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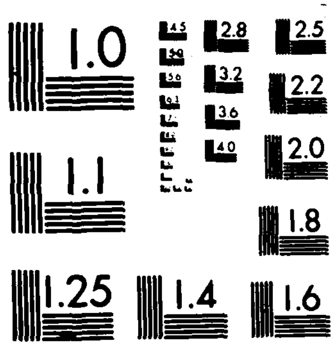

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AD-A175 419

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This is a synoptic report describing water quality and composition and distribution of benthic macroinvertebrates, larval fishes, and fishes within a 62-mile reach of the lower Mississippi River. Major water quality differences among habitats were related to the presence or absence of current. Continual flow and high turbulence in lotic habitats such as the main channel and permanent secondary channel resulted in high suspended solids concentrations, high

(Continued)

20. ABSTRACT (Continued).

turbidities, low water transparencies, and low light penetration. Such physical characteristics resulted in low algal biomass, more stable pH and dissolved oxygen levels, and the constant availability of algal nutrients. In contrast, lentic areas, such as the abandoned channel at most river stages, and the dike fields at low flows, had relatively lower suspended solids and increased water clarity. This resulted in high algal biomass, higher pH readings, frequent dissolved oxygen supersaturation in surface waters, and nutrient depletion in slack-water areas.

The distribution of macroinvertebrates in the lower Mississippi River is a function of the physical characteristics of the system, notably current velocity and substrate composition. Natural banks were consistently dominated by the clay-burrowing mayflies *Tortopus incertus* and *Pentagenia vittigera*, and hydropsychid caddisflies; the consistently most common taxa in the permanently flowing secondary channel were the sand-dwelling chironomids *Robackia claviger* and *Chernovskiia orbicus*; phantom midges, tubificid oligochaetes, and fingernail clams were always the most abundant macroinvertebrates in the slack-water abandoned channel. However, the dike fields showed large changes in biotic composition over different flow regimes. These biotic changes corresponded with alterations in current and substrate. The rock dike structures were densely colonized by epibenthic organisms.

Three principal factors determine ichthyoplankton composition and distribution: larval phenology, habitat characteristics, and river stage. The progeny of early spawners such as gizzard shad, mooneye, goldeye, carp, buffaloes, and sauger dominated spring and early summer ichthyoplankton collections, while freshwater drum, carpsuckers, and *Lepomis* spp. dominated the mid to late summer ichthyoplankton community. Ichthyoplankton composition in the backwaters (shad, *Lepomis* spp., and silversides) was markedly dissimilar from that of the main channel (drum and carpsuckers). Isolated dike field pools were populated by larval fishes typical of backwater habitats. In general, backwater and slack-water habitats supported much higher ichthyoplankton densities than lotic areas.

The lower Mississippi River possesses a number of fish species which are restricted to (bullheads, bowfin, and spotted gar) or prefer backwater areas (bluegill, largemouth bass, white and black crappies, paddlefish, and alligator gar). Swift current areas of the lower Mississippi support shovelnose sturgeon (fairly common), blue sucker (fairly common), and blue catfish (abundant) populations; these three species have all suffered major declines in abundance in the impounded upper Mississippi. Dike fields have diverse fish faunas. This diversity is a product of physical structure and the varying of physical conditions within the dike fields with changing river stages. The dike fields' middle bars furnish large shallow "shoreline" areas which are populated by a diverse and abundant community of small fish species and young-of-the-year fishes or larger species.

These studies have shown that the abandoned channel and dike field pool habitats are of special concern and importance. The placement of dikes and revetments along the river has prevented channel meandering by "locking" the river into a permanent alignment. Consequently, abandoned channels are rarely created now. Existing abandoned channels should therefore be protected from filling in or being dewatered. The formation of lake-like pools in the dike fields during low flow is precluded by the filling in of these areas. Engineering practices which would prevent or delay the "terrestrialization" of dike fields should be encouraged in the lower Mississippi River.

PREFACE

This study was sponsored by the Office, Chief of Engineers (OCE), US Army, under the Environmental and Water Quality Operational Studies (EWQOS) Program, Work Units VA, Environmental Impact of Selected Channel Alignment and Bank and Revetment Alternatives in Waterways, and VIIB, Waterway Field Studies. The OCE Technical Monitors for EWQOS were Mr. Earl E. Eiker, Dr. John Bushman, and Mr. James L. Gottesman. The EWQOS Program has been assigned to the US Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL).

This report was prepared by Drs. David C. Beckett and C. H. Pennington, both of EL. This study was conducted under the supervision of Dr. Thomas D. Wright, Chief, Aquatic Habitat Group; and Dr. Conrad J. Kirby, Jr., Chief, Environmental Resources Division. Dr. Jerome L. Mahloch was Program Manager, EWQOS. Dr. John Harrison was Chief, EL. The report was edited by Ms. Jamie W. Leach of the WES Information Products Division.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee is the present Commander and Director. Dr. Robert W. Whalin is the Technical Director.

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CONVERSION FACTORS, US CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

US customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
feet	0.3048	metres
feet per second	0.3048	metres per second
miles (US statute)	1.609347	kilometres

WATER QUALITY, MACROINVERTEBRATES, LARVAL FISHES, AND FISHES OF THE LOWER MISSISSIPPI RIVER--A SYNTHESIS

PART I: INTRODUCTION

Background

1. This synthesis is part of the Environmental and Water Quality Operational Studies (EWQOS) Program sponsored by the Office, Chief of Engineers, and managed by the US Army Engineer Waterways Experiment Station. Historically the US Army Corps of Engineers has been deeply involved in the use and development of large rivers as navigable waterways. As a consequence of this involvement, the EWQOS Waterway Field Studies were initiated to perform ecological studies on a number of these large rivers. A principal objective of the EWQOS Waterway Field Studies is to provide data on how control structures for channel alignment, channel straightening, and bank stabilization affect waterway ecology. Such river control structures are found in navigable rivers in various parts of the United States, and are especially common in the Mississippi River and its tributaries.

2. This report describes water quality and composition and distribution of benthic macroinvertebrates, larval fishes, and fishes within a 62-mile* reach of the lower Mississippi River and is the synoptic report in the EWQOS series dealing with the aquatic habitats and biota of the lower Mississippi River. Early reports identified and characterized aquatic habitats (both natural and man-made) within the study area (Miller 1981, Cobb and Clark 1981). Following the characterization of aquatic habitats, pilot studies investigated various aspects of the ecology of benthic invertebrates (Mathis et al. 1981), larval fishes (Schramm and Pennington 1981), and fishes (Pennington et al. 1980). Additional studies in the same study area dealt with macroinvertebrate

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* A table of factors for converting US customary units of measurement to metric (SI) is presented on page 7.

drift (Bingham, Cobb, and Magoun 1980) and the assessment of macroinvertebrate colonization of stone dikes (Mathis, Bingham, and Sanders 1982). The pilot studies were summarized by Wright (1982). Following the completion of the pilot studies, intensive studies regarding water quality (Sabol, Winfield, and Toczydlowski 1984), benthic macroinvertebrates (Beckett et al. 1983), larval fishes (Conner, Pennington, and Bosley 1983), and fishes (Pennington, Baker, and Bond 1983) of the lower Mississippi River were conducted. This synthesis document summarizes and discusses the findings of these various EWQOS studies.

Organization of Synthesis

3. This document is organized into six parts and two appendices. This introduction (Part I) is followed by a brief discussion of the study area and the principal study habitats (Part II). Parts III, IV, V, and VI deal with water quality, benthic macroinvertebrates, larval fishes, and fishes, respectively. Figures and tables are placed in the text near the point at which they are first cited and are numbered consecutively throughout the text. Although this synthesis document is intended to be approached in its entirety, Parts III, IV, V, and VI each have their own introduction (including a brief description of methods), results, and discussion. Thus, a reader interested in a certain organismal group (macroinvertebrates, larval fishes, or fishes) can have access to a cohesive treatment of that set of organisms. References cited are listed in a single section at the end of the text. Appendix A is a sediment particle-size classification; Appendix B is an autecological treatment of the fishes, organized by families.

PART II: STUDY AREA

4. The primary study area encompasses a 62-mile reach of the lower Mississippi River (river miles 504-566 above Head of Passes), near Greenville, Mississippi (Figure 1). The study area is laterally confined to the river's floodplain (2-6 miles wide) by main-line levees. No tributaries enter this section of the river. However, backwater areas such as abandoned channels, borrow pits, and oxbow lakes lie within the restricted floodplain and are occasionally contiguous with the river, especially at high flows. The study area contains a variety of natural habitats, e.g. clay banks, sandbars, permanent and temporary secondary channels, and abandoned channels. Other habitats, constructed by the Corps of Engineers, include revetted banks and dike fields containing variously designed stone dikes. These habitats are physically most distinct at low flow periods since at high flows most or all of the area between the levees may be inundated. Descriptions of lower Mississippi River aquatic habitats are presented in Cobb and Clark (1981).

5. River stages, as measured on the Vicksburg, Mississippi, gauge, have varied yearly as much as 60 ft; however, during 1978-1980, river stage had a yearly maximum range of approximately 36 ft (Figure 2). Main channel water velocity is usually between 3 and 6 ft/sec with a maximum recorded velocity of 15 ft/sec. Highest discharges generally occur from February through April with lowest discharges from July through October.

6. Five habitats, including seven sites, were frequently used for sampling water quality, benthos, larval fishes, and fishes. These sites include three dike fields (Lower Cracraft, Leota, and Chicot Landing), a natural bank area (Anconia Natural Bank), a revetted bank (Walnut Point-Kentucky Bend Revetment), a permanent secondary channel (American Cutoff), and an abandoned channel (Matthews Bend). "Dike field" refers to the areas of water (and river bottom) immediately preceding the upstream dike, between the dikes, and immediately following the downstream dike. Other representatives of each of these habitat types were also sampled, mostly during the pilot studies. However, since these seven

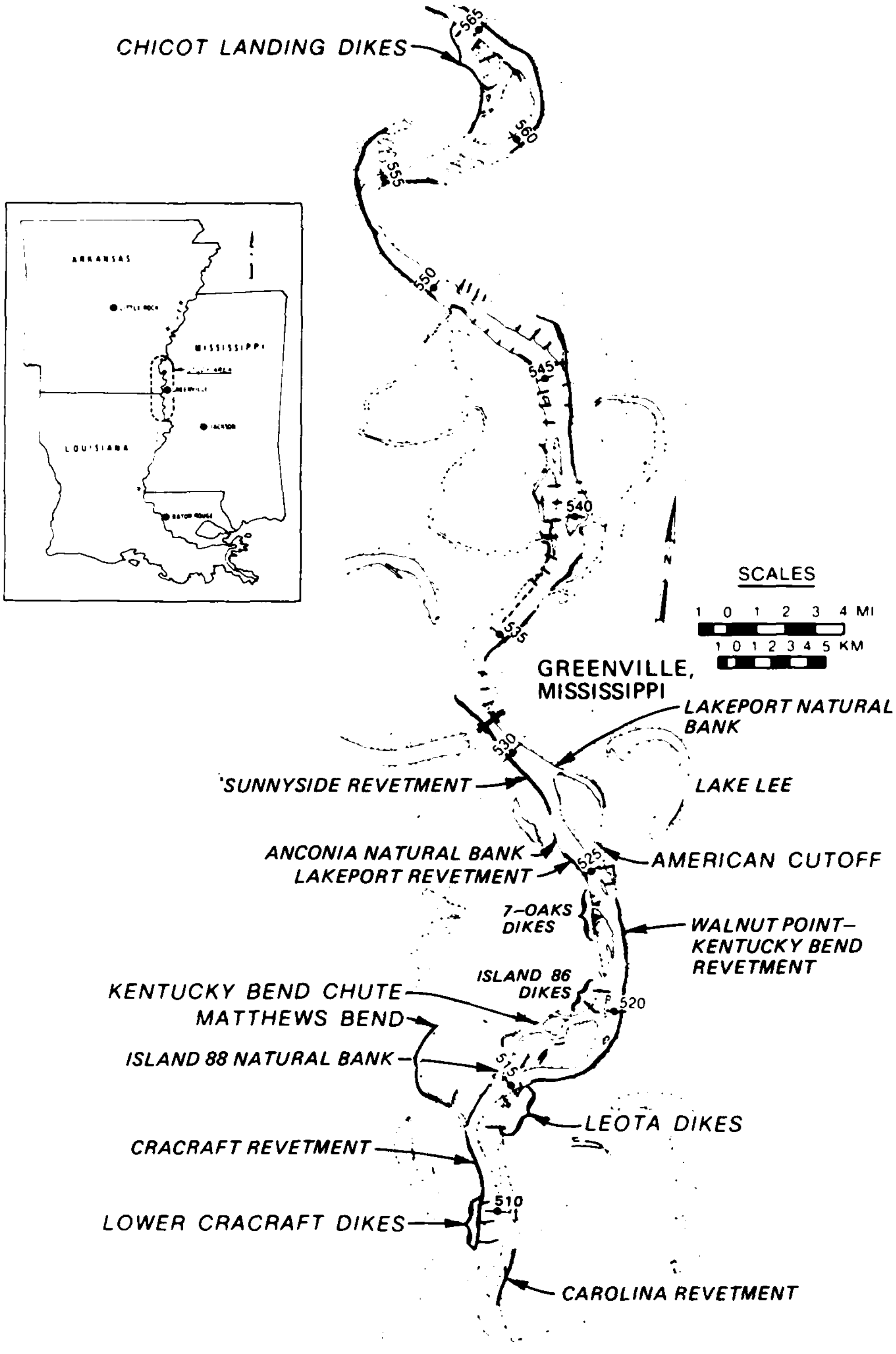


Figure 1. Study area

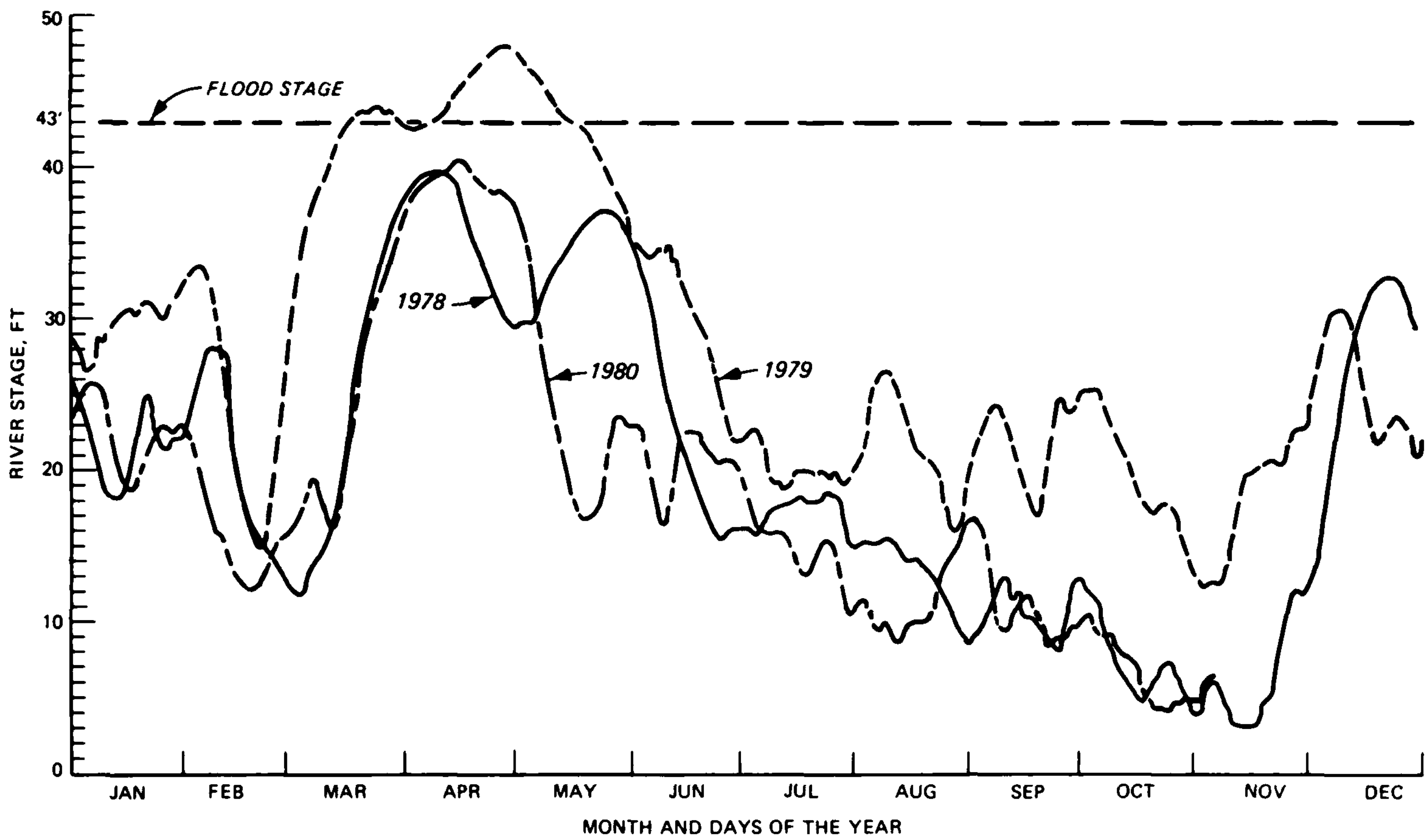


Figure 2. Mississippi River stage in 1978-1980. Readings taken at the Vicksburg, Miss., gauge

study sites were used so extensively and are continually referred to throughout this text, we have included a brief description of each site below.

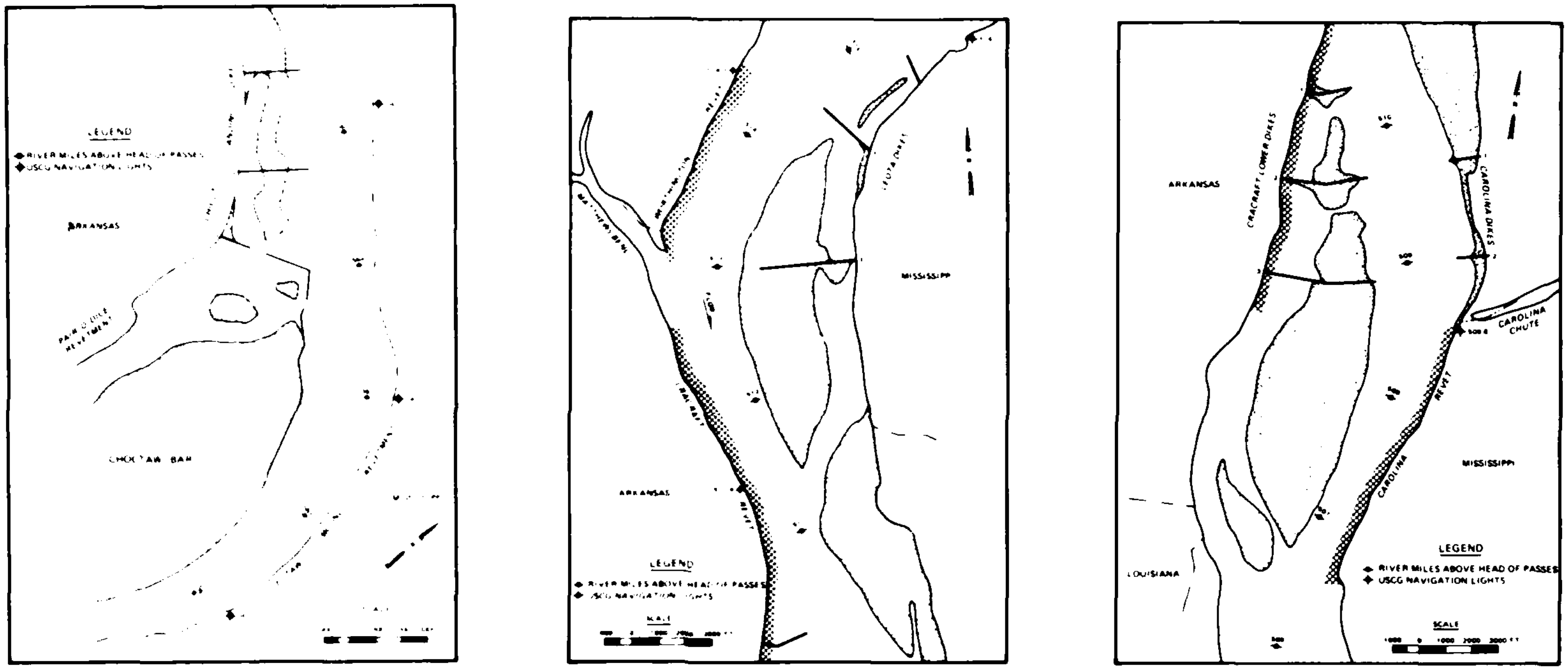
Dike Fields - Lower Cracraft, Leota, and Chicot Landing

7. Both Lower Cracraft (river miles 506.5-511.0) and Leota (river miles 511.5-515.5) Dike Fields consist of three transverse stone dikes constructed for the dual purpose of secondary channel closure and point bar stabilization (Figure 3). Chicot Landing Dike Field (river miles 562.0-565.5) was constructed to divert flow away from the secondary channel behind Choctaw Bar and consists of two transverse dikes followed by a third L-head dike (Figure 3). The third dike has suffered a breach failure in the transverse leg while a gap was left in the L-head portion of the dike during construction. Consequently, this dike now has a notch in each leg of the L.

8. As in the case of most lower Mississippi River dike fields, extensive sand and gravel middle bars occur between succeeding dikes (and below the last dike) at all three dike fields (Figure 3). These middle bars, the main axis of which is parallel to the main channel flow, isolate extensive pools from main channel flow during low river discharge periods, confining the dike field pools between the dikes, the river bank, and the middle bars. Stands of cottonwoods and willows occur on the larger middle bars. At high river stages the middle bars and the stone dikes themselves are underwater and current velocities in the dike field areas approach those of the main channel.

Anconia Natural Bank

9. Anconia Natural Bank (river miles 526.0-527.3) is an unprotected (non-revetted) river bank along the main channel (Figure 4). The bank is steep (slope usually greater than 30 percent) and is composed of

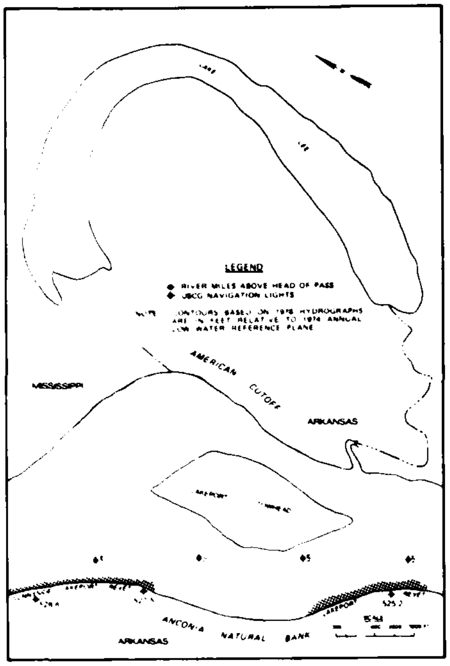


a. Chicot Landing Dike Field

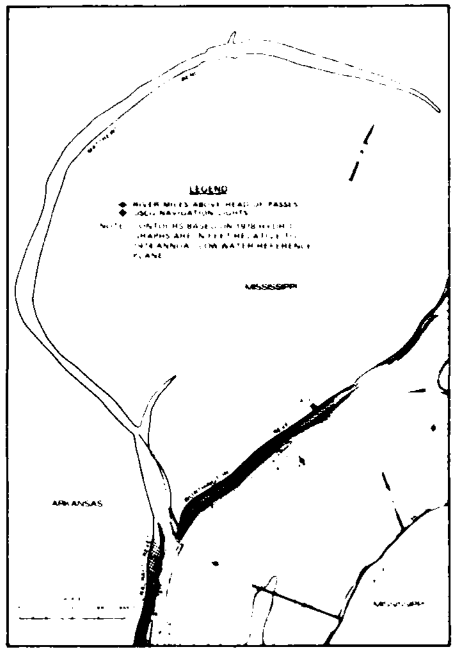
b. Leota Dike Field

c. Lower Cracraft Dike Field

Figure 3. Dike field sampling sites. Stippled areas are middle bars



a. Anconia Natural Bank and American Cutoff



b. Matthews Bend

Figure 4. Aconia Natural Bank, American Cutoff (permanent secondary channel), and Matthews Bend (abandoned channel) sampling areas

clays interspersed with sand layers. Fallen trees and snags are generally common and present an additional substrate (along with the bank itself) for macroinvertebrate colonization.

Walnut Point-Kentucky Bend Revetted Bank

10. The Walnut Point-Kentucky Bend Revetment is approximately 8 miles long (river miles 516-524) and was placed over the existing bank during 1944-1968. The revetment material consists of articulated concrete mattress with an upper-bank paving of stone riprap and asphalt. Although substrate generally consists of the revetting material, isolated areas of sand and sand/silt overlaying the revetment also occur. As in the case of many revetted banks on the lower Mississippi, current speed is high at Walnut Point-Kentucky Bend Revetment, commonly exceeding 3 ft/sec.

American Cutoff

11. American Cutoff (river miles 525.2-528.3) is a permanent (year-around flow maintained) secondary channel (Figure 4). Although the secondary channels are subordinate to the main channel in terms of flow-carrying capacity, environmental conditions are very similar to those of the main channel. Substrates in this area are typically coarse sand although depositional areas are present along certain stretches of the east-bank side.

Matthews Bend

12. Matthews Bend (contiguous with the river at river mile 513.0) is an abandoned river channel (Figure 4). At low water Matthews Bend is approximately 5 miles long from its confluence with the main channel to its head, with depth increasing downstream. At high flows some water from the river enters upstream and moves through the channel creating some current. At moderate and low flows, however, the entire area is a backwater. This area has a mud substrate during all flow conditions.

PART III: WATER QUALITY

Introduction

13. This section deals with water quality in the lower Mississippi River, and is largely a summary of the EWQOS report "Investigation of Water Quality and Plankton in Selected Aquatic Habitats on the Lower Mississippi River" by Sabol, Winfield, and Toczydlowski (1984). The primary objectives of that study were to quantitatively describe and compare physical, chemical, and biological conditions in several lower Mississippi River habitats, including a dike field, the main channel, an abandoned channel, and a secondary channel. Variables examined in that study were those deemed ecologically significant, i.e., important to or indicative of aquatic life. These included the following:

- a. Physical variables: current velocity, temperature, water transparency, suspended solids, and specific conductance.
- b. Chemical variables: dissolved solids, alkalinity, pH, free-carbon dioxide, dissolved oxygen, oxidation-reduction potential, and algal macro-nutrients, including nitrite-nitrate nitrogen, ammonia nitrogen, total phosphorus, and dissolved orthophosphate.
- c. Biological variables: photosynthetic pigment (indicative of algal density), zooplankton density and composition, and particulate and dissolved organic matter.

Description of Study Area

14. The study area encompassed a 62-mile reach of the lower Mississippi River near Greenville, Mississippi (Figure 1, river miles 504-566). The five habitats studied included the main channel, dike fields (Chicot Landing, Leota, and Lower Cracraft), a permanent secondary channel (American Cutoff), a temporary secondary channel (Kentucky Bend Chute), and an abandoned river channel (Matthews Bend). Flow is maintained through the temporary secondary channel at high discharges. At lower discharges, however, Kentucky Bend Bar becomes contiguous with the shoreline, flow is cut off, and the secondary channel becomes a

pool. Descriptions of the three dike fields, the permanent secondary channel, and the abandoned channel may be found in Part II of this document. More detailed descriptions of lower Mississippi River habitat types may be found in Cobb and Clark (1981).

Methods

15. A two-phase sampling program included monthly sampling at seven stations in four habitats from November 1979 through September 1980 and low water sampling in four habitats in September 1980. The monthly sampling included two main channel stations, two stations in Lower Cracraft Dike Field, two stations in Matthews Bend, and one station in Kentucky Bend Chute.

16. The low water study, a spatially intensive effort conducted from 10-17 September 1980, included stations from three dike fields (Chicot Landing, Leota, and Lower Cracraft), Matthews Bend, American Cutoff, and the main channel. Sampling at each habitat took place on one day during the 10-17 September interval. During the low water study all habitats except the main channel, pool 3 of Chicot Landing Dike Field (below the third dike), and American Cutoff had assumed lentic characteristics. Sampling within a given habitat was begun by midmorning and was always completed by early afternoon. Detailed descriptions of sampling procedures, data collection, and analyses may be found in Sabol, Winfield, and Toczydlowski (1984).

Results

Monthly sampling phase - physical

17. Interpretation of the data requires knowing whether station conditions were lentic or lotic at the time of sampling. During the study period river stage* varied between a low of ca. 8.5 ft (259,880 cfs, estimated flow) on 11 August 1980 to a high of ca. 40.5 ft

* Measured at Vicksburg, Miss., gauge.

(1,200,540 cfs, estimated flow) on 10-13 April 1980 (Figure 2). All study habitats, except the main channel, were lentic for variable periods of time, ranging from Matthews Bend, which was lentic for all periods except April, to pool 3 of the Lower Cracraft Dike Field and Kentucky Bend Chute, which were lentic only during November, May, August, and September (Table 1).

18. Main channel stations tended to have the coolest temperatures and ranged from 5.0°C in December to 32.0°C in August (Figure 5). The highest temperatures were consistently from Matthews Bend (from a low of 8.0°C in December to a high of 34.5°C in August), the most lentic of the stations. Over the study period the monthly mean Matthews Bend surface water temperatures averaged 2.7°C warmer than the corresponding monthly mean for main channels. Even when flooding occurred in April, the surface water temperature of Matthews Bend averaged 2.3°C warmer than the mean main channel surface water temperature. Surface water temperatures at other stations tended to vary between the lower temperatures of the main channel stations and the higher temperatures of the Matthews Bend stations. Lower Cracraft Dike Field pool 1 (below the first dike) and pool 3 averaged 0.6°C and 0.4°C, respectively, warmer than the mean for main channel stations. Temperatures in the temporary secondary channel were not detectably different from that of the main channel stations.

19. During lentic conditions, marked thermal stratification occurred at both stations in Matthews Bend and in the pools of Lower Cracraft Dike Field. At the deeper station in Matthews Bend (nearer the mouth of the abandoned channel) surface to bottom temperature differences ranged from a low of 1.2°C in December to 16.0°C in August (bottom temperatures were always less than corresponding surface temperatures). Surface to bottom temperature differences at the shallower Matthews Bend sampling area were generally less, with a maximum ΔT of 5.5°C recorded in June. Maximum surface to bottom temperature differences were 5.0°C and 9.5°C for Lower Cracraft's pool 1 and 3, respectively.

20. Suspended solids and turbidity readings showed similar patterns, with the main channel values consistently much higher than those of Matthews Bend (Table 2). Values for Lower Cracraft Dike Field and

Table 1

Duration of Lentic Conditions at Time of Monthly Sampling*

Sampling Date	Station or Habitat: Lower Cracraft Dike Field: Pool 1	Pool 3	Kentucky Bend Chute	Matthews Bend
6-9 Nov 1979	L-15**	L-13	-	L-165
20 Dec 1979	R	R	R	L-206
16-17 Jan 1980	R	R	R	L-234
26-28 Feb 1980	L-20	R	R	L-265
18-19 Mar 1980	R	R	R	L-284
22-23 Apr 1980	R	R	R	R
20 May 1980	L-3	L-1	L-1	L-20
19 Jun 1980	R	R	R	L-50
23 Jul 1980	R	R	R	L-84
15 Aug 1980	-	L-22	L-22	L-105
9 Sept 1980	L-6	L-4	L-4	L-130

R = riverine state (measurable current).
L = lentic state (no detectable current).
- = no samples taken.
* Main channel sampling stations were always in a riverine state (measurable current present).
** Numerals refer to approximate number of days in lentic state at the time of sampling.

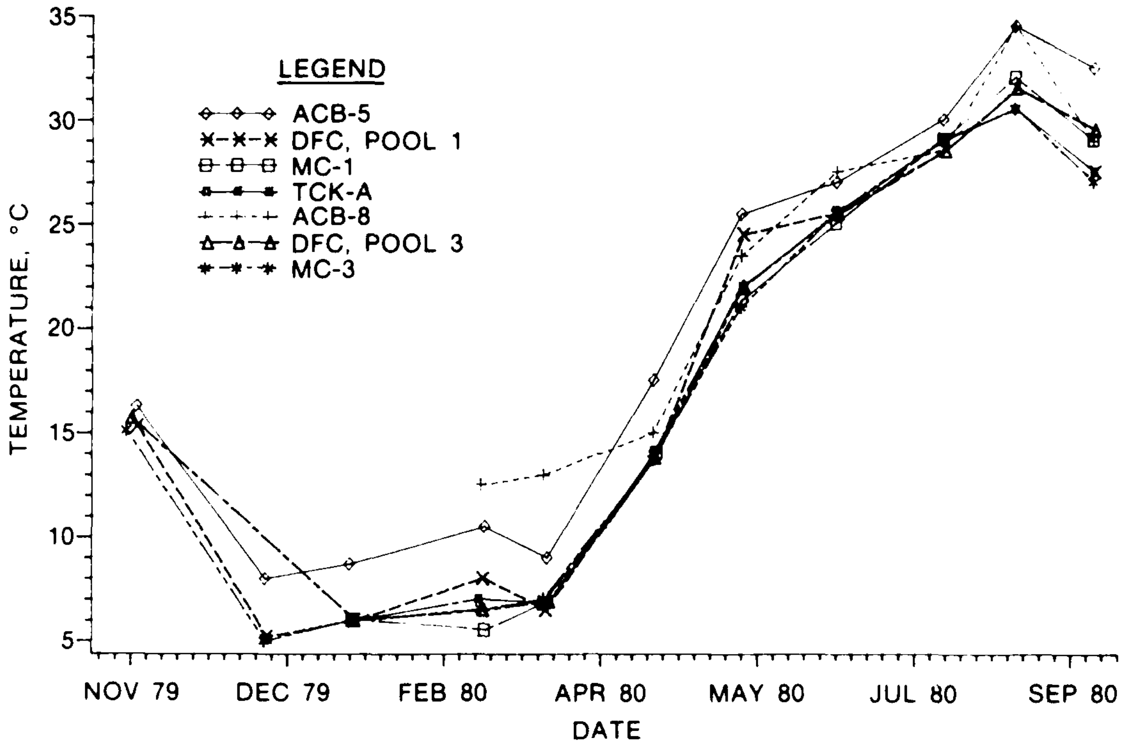


Figure 5. Monthly temperatures at lower Mississippi River study sites. ACB = abandoned channel (Matthews Bend): ACB-5 and ACB-8 are located 2.3 km and 6.4 km, respectively, from the confluence with the river. DFC = Lower Cracraft Dike Field; TCK = temporary secondary channel (Kentucky Bend Chute); MC = main channel

Kentucky Bend Chute varied between those of the main channel and the abandoned channel, i.e., during lotic periods suspended solids and turbidities at the dike field and Kentucky Bend were similar to those of the main channel; during lentic periods Lower Cracraft's and Kentucky Bend's values were similar to those of the backwater at Matthews Bend. As would be expected, Secchi disk readings, which indicated water transparency, showed an inverse relationship with turbidity (Table 2). The main channel had the lowest Secchi depth observed (11 cm) and lowest mean Secchi depth (22 cm) over the year while Matthews Bend had the greatest single Secchi depth (104 cm) and the greatest mean Secchi depth (55 cm).

Monthly sampling phase - chemical

21. The main channel, dike field, and temporary secondary channel

Table 2

Physical Water Quality Variables for Selected Stations Sampled Monthly

from November 1979 to September 1980

		Stations						
		Main Channel		Matthews Bend		Lower Cracraft Dike Field		Temporary Channel
Parameter	Statistic	MC-1	MC-3	ACB-5*	ACB-8*	Pool 1	Pool 3	TCK-A
Current speed cm/sec	Mean (overall)	145	155	1	0	27	43	62
	(when detected)	145	155	10	-	48	71	93
	N	9	11	11	8	9	10	9
	Frequency detected (% of samplings)	100	9	9	0	56	60	67
	Minimum	93	103	0	0	0	0	0
	Maximum	196	242	10	0	98	139	144
Suspended solids mg/ℓ	Mean (overall)	90.3	117.2	22.0	39.2	76.5	55.3	73.4
	(lentic)	-	-		39.2	32.0	13.8	27.7
	(lotic)	90.3	117.2		-	106.2	88.5	96.3
	N	11	11	11	8	10	9	9
	Minimum	53.7	67.7	7.2	22.9	16.5	9.7	16.3
	Maximum	186.0	186.0	54.2	66.0	162.0	145.0	150.0
Secchi disk depth, cm	Mean (overall)	22	23	55	48	30	43	30
	(lentic)	-	-		48	48	70	46
	(lotic)	22	23		-	21	25	19
	N	9	11	10	8	9	10	8
	Minimum	11	11	30	23	11	11	14
	Maximum	36	36	104	102	58	91	63
Turbidity, NTU**	Mean (overall)	42	39	16	14	34	[illegible]	24
	(lentic)	-	-	15	14	14	9	13
	(lotic)	42	39	24	-	56	45	44
	N	10	10	10	8	9	10	9
	Minimum	23	10	6	7	10	7	10
	Maximum	63	64	52	34	66	62	61
Specific conductance μmhos/cm	Mean	422	417	506	556	421	433	422
	N	9	11	11	8	10	10	9
	Min	365	365	365	385	355	360	360
	Max	490	490	667	720	500	490	510

* ACB-5 and ACB-8 are located in Matthews Bend 2.3 km and 6.4 km, respectively, from the confluence with the river.

** NTU = Nephelometric turbidity units.

had similar within-date values for specific conductance (Figure 6), dissolved solids, and total alkalinity (Table 3). The abandoned river channel (Matthews Bend) generally had higher alkalinities and specific conductance values than the other habitats. During April, however, when very high river stages occurred and Matthews Bend flooded, these chemical characteristics (specific conductance, dissolved solids, and total alkalinities) were similar at all habitats (including Matthews Bend).

22. A comparison of surface pH and free-CO_2 levels at lotic vs. lentic areas showed an interesting dichotomy. Minimum pH levels were similar at all habitats (7.4-7.7) (Table 3). However, maximum pH at the lotic habitats (main channel and Kentucky Bend Chute) reached only 8.1, while the maximum pH was 8.7 at Matthews Bend and 8.9 in Lower Cracraft Dike Field. Some free-CO_2 was always present in the main channel stations; however, free-CO_2 was not detected at the abandoned channel

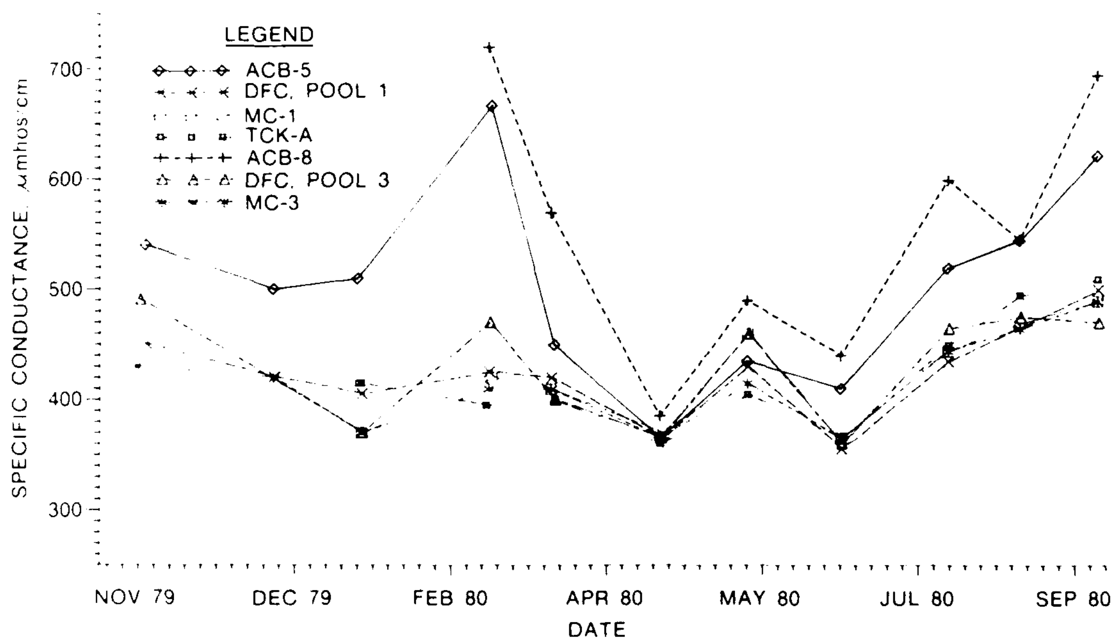


Figure 6. Monthly specific conductance values at lower Mississippi River study sites. ACB = abandoned channel (Matthews Bend): ACB-5 and ACB-8 are located 2.3 km and 6.4 km, respectively, from the confluence with the river. DFC = Lower Cracraft Dike Field; TCK = temporary secondary channel (Kentucky Bend Chute); MC = main channel

Table 3

Chemical Water Quality Variables for Selected Stations Sampled Monthly from November 1979 to September 1980

Parameter	Statistic	Main Channel MC-1	Main Channel MC-3	Matthews Bend ACB-5*	Matthews Bend ACB-8*	Lower Cracraft Dike Field Pool 1	Lower Cracraft Dike Field Pool 3	Kentucky Bend Chute TCK-A
Dissolved solids mg/ℓ	Mean	292	293	317	368	283	308	312
	N	11	11	11	8	10	10	8
	Min	233	220	250	260	230	242	239
	Max	546	532	376	462	403	552	576
Total alkalinity mg/ℓ as $CaCO_3$	Mean	126	122	195	237	150	126	124
	N	10	10	11	8	9	9	9
	Min	102	97	97	96	96	95	96
	Max	150	146	320	346	350	174	168
pH	Mean	7.8	7.8	7.9	7.9	7.9	7.8	7.8
	N	9	10	11	8	10	10	9
	Min	7.7	7.6	7.4	7.4	7.5	7.6	7.4
	Max	8.1	8.0	8.7	8.5	8.9	8.4	8.1
Free-CO_2, mg/ℓ	Mean	3.3	3.9	1.6	3.6	2.8	3.5	3.2
	N	8	10	11	8	9	9	9
	Frequency detected, %	100	100	45	50	78	89	100
	Min	2.0	2.2	0	0	0	0	0.8
	Max	4.4	6.0	6.2	8.8	6.0	8.2	6.0
Dissolved oxygen mg/ℓ	Mean	8.7	9.1	12.7	11.0	10.5	9.4	9.0
	N	9	11	11	8	10	10	9
	Min	6.2	6.3	6.3	4.4	6.5	6.5	6.0
	Max	11.7	12.8	23.2	18.4	16.6	13.2	12.2
Dissolved oxygen % saturation	Mean (overall)	88.4	89.0	143.3	125.7	102.7	96.6	92.2
	(lentic)					125.7	105.4	97.7
	(lotic)					87.4	90.7	89.4
	N	9	11	11	8	10	10	9
	Min	77.7	78.6	63.7	56.4	77.7	76.9	74.0
	Max	103.8	103.9	326.0	258.6	181.2	147.1	119.7

* ACB-5 and ACB-8 are located in Matthews Bend 2.3 km and 6.4 km, respectively, from the confluence with the river.

stations on approximately half the sampling dates (Table 3). Free-CO_2 was also occasionally not detected at the dike field sampling stations.

23. A comparison of surface dissolved oxygen values shows 4.4 mg/ℓ as the lowest level encountered (Table 3). Matthews Bend and Lower Cracraft's surface dissolved oxygen concentrations periodically showed evidence of supersaturation. A concentration of 23.2 mg/ℓ was detected at Matthews Bend and a 16.6-mg/ℓ concentration was measured at Lower Cracraft Dike Field. While dissolved oxygen levels often reached supersaturation in the surface waters of Matthews Bend and Lower Cracraft Dike Field, anoxic conditions occasionally occurred in the bottom waters of both habitats. Bottom water dissolved oxygen concentrations measured in Matthews Bend were all greater than 5 mg/ℓ during the cooler months (November-April). However, on the May through August sampling dates, the bottom waters at the Matthews Bend stations were devoid of oxygen. Lower Cracraft Dike Field stations showed a somewhat similar pattern. Even under lentic conditions the dike field's bottom waters contained ample oxygen during the cooler months. During warmer months anoxic conditions were observed at the deeper pool 3 station, but not at the shallower pool 1 station.

24. The oxidation-reduction potential (ORP) of oxygenated or surface waters is not quantitatively interpretable (Wetzel 1975, Gunnison and Brannon 1981) and was used solely to indicate the occurrence and extent of highly reduced conditions suitable for the generation of H_2S (ORP values of less than 100 mv (Cole 1975)). ORP values below 100 mv were observed in bottom waters of Matthews Bend at the deeper sampling station in August and September and at the shallower station in July. An ORP value below 100 mv was observed in bottom waters of Lower Cracraft pool 3 in August.

25. Among the three stations (main channel, Matthews Bend, and pool 1 of Lower Cracraft Dike Field) sampled for nutrients during the monthly study, the main channel had the highest mean nitrite-nitrate nitrogen values and the highest average total phosphorus and dissolved orthophosphate concentrations (Table 4). Matthews Bend had the lowest average concentrations for these parameters. While the various nutrient

Table 4

Nutrient Concentrations for Selected Stations Sampled Monthly from November 1979 to September 1980

Parameter	Statistic	Stations: Main Channel MC-3	Stations: Matthews Bend ACB-5*	Stations: Lower Cracraft Dike Field Pool 1
$NO_2 + NO_3$, mg N/ℓ	Mean	1.259	0.428**	0.980**
	N	11	11	9
	Frequency detected, %	100	73	89
	Min	0.764	0.010	0.010
	Max	2.060	1.340	2.030
NH_3, mg N/ℓ	Mean	0.290	0.237**	0.249
	N	11	11	8
	Frequency detected, %	100	91	100
	Min	0.020	0.010†	0.040
	Max	1.340	0.620	1.070
Total phosphorus mg P/ℓ	Mean	0.30**	0.120**	0.25**
	N	11	11	9
	Frequency detected, %	91	73	89
	Min	0.10††	0.10††	0.10††
	Max	0.79	0.47	0.77
Dissolved orthophosphate mg P/ℓ	Mean	0.046	0.018**	0.029**
	N	11	11	9
	Frequency detected, %	100	36	78
	Min	0.013	0.010	0.010
	Max	0.080	0.040	0.080

* ACB-5 is located in Matthews Bend 2.3 km from the confluence with the river.

** Means computed using the detection limit for those concentrations ≤ the detection level.

† Detection limit is 0.010 mg/ℓ. Those concentrations ≤ 0.010 mg/ℓ are shown as 0.010.

†† Detection limit is 0.10 mg/ℓ. Those concentrations ≤ 0.10 mg/ℓ are shown as 0.10.

concentrations were always above detectability in the main channel, nitrite-nitrate nitrogen, total phosphorus, and dissolved orthophosphate were frequently below the level of detectability in Matthews Bend (Table 4). In fact, nitrite-nitrate nitrogen concentrations and dissolved orthophosphate concentrations remained continually low at Matthews Bend except during the high water periods when turbid riverine water was observed in the abandoned channel.

Monthly sampling phase - biological

26. Investigations conducted prior to the beginning of water quality sampling showed that trichromatic chlorophyll *a* (hereafter called chlorophyll *a*) exhibited the greatest sampling and analytical precision among the individual chlorophyll pigments (Sabol, Winfield, and Toczydlowski 1984). Because of the relatively high precision associated with this pigment, and because it is common to all taxa of phytoplankton, chlorophyll *a* was the sole pigment used as a quantitative indicator of phytoplankton density. Main channel stations, Kentucky Bend Chute, and Lower Cracraft pool 3 had relatively low chlorophyll *a* concentrations, except during May and August (Figure 7, Table 5). Concentrations in Matthews Bend were most frequently greater than those at stations in other habitats, with large peaks in February and August. Concentrations at Lower Cracraft Dike Field pool 1 were similar to main channel stations during lotic sampling periods; during lentic sampling periods concentrations increased above those at main channel stations, but rarely reached the concentrations at Matthews Bend stations.

27. Zooplankton collected as part of the monthly study (zooplankton collected from January to September) consisted primarily of loricate rotifers, copepod nauplii, and ciliated protozoans, in that order. Adult copepods, cladocerans, various insect larvae, ostracods, nematodes, and oligochaetes were encountered, although they were numerically rare. A summary of surface water zooplankton densities at the seven monthly sampling stations (Table 5) showed that the greatest mean densities occurred at Matthews Bend stations with least numbers in the main channel stations; the range of means between stations was almost an

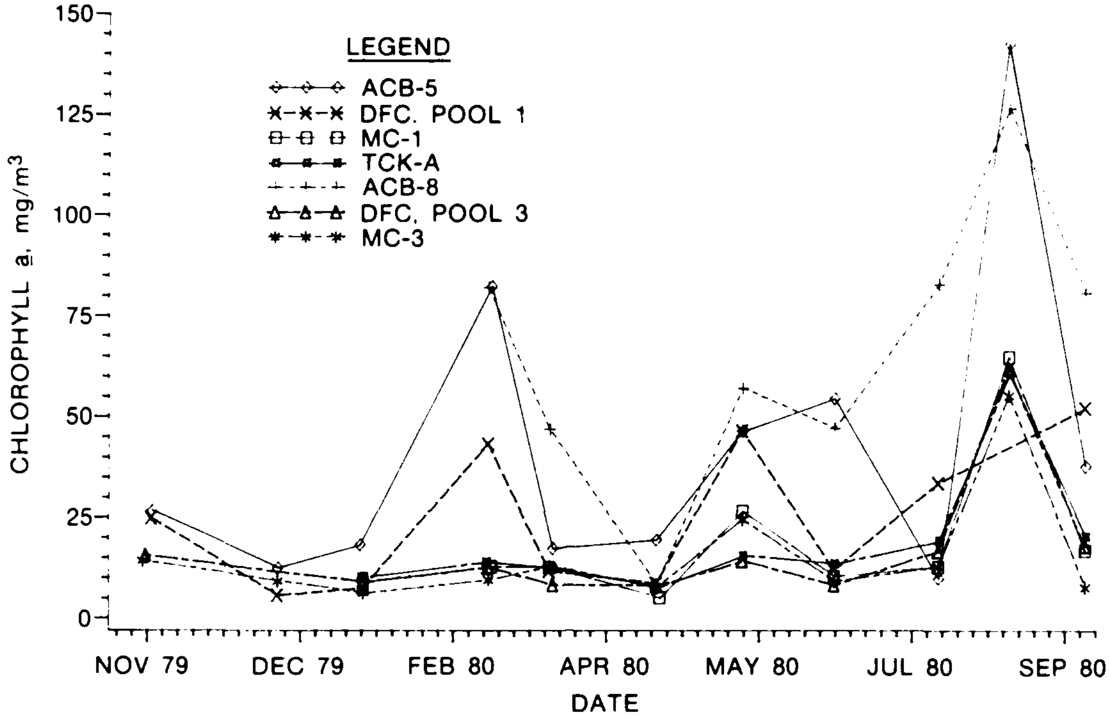


Figure 7. Monthly chlorophyll a values for lower Mississippi River study sites. ACB = abandoned channel (Matthews Bend): ACB-5 and ACB-8 are located 2.3 km and 6.4 km, respectively, from the confluence with the river. DFC = Lower Cracraft Dike Field; TCK = temporary secondary channel (Kentucky Bend Chute); MC = main channel

order of magnitude. Within station variation over the study period approached two orders of magnitude.

28. *Keratella* spp. (rotifers) (principally *K. cochlearis*) followed by *Vorticella* (Protozoa), copepod nauplii, *Brachionus* spp. (rotifers) (principally *B. calciflorus*), and *Polyarthra* (rotifer) were most numerous at the relatively depauperate main channel stations. At the zooplankton rich Matthews Bend stations, *Brachionus* (*B. anularis*, *B. calciflorus*, and *B. caudata*), *Polyarthra*, *Keratella* (principally *K. cochlearis*), and copepod nauplii, in that order, were most numerous. The rotifers *B. angularis*, *B. caudata*, *Polyarthra*, *Trichocerca*, *Synchaeta*, *Asplanchna*, *Pompholyx*, *Monostyla*, and *Filinia* were relatively plentiful at one or both of the Matthews Bend stations, but rare at main channel stations. The protozoan *Vorticella*, plentiful at main channel

Table 5

Biological Variables from Selected Stations Sampled Monthly from November 1979 to September 1980

Parameter	Statistic	Main Channel MC-1	Main Channel MC-3	Matthews Bend ACB-5*	Matthews Bend ACB-8*	Lower Cracraft Dike Field Pool-1	Lower Cracraft Dike Field Pool-3	Kentucky Bend Chute TCK-A
Chlorophyll *a* mg/m^3	Mean	18.8	15.3	42.4	66.4	24.5	17.1	19.1
	N	9	11	11	8	10	10	9
	Min	4.9	6.1	9.9	8.3	5.6	8.0	7.4
	Max	69.7	55.2	142.7	126.6	52.1	61.9	60.7
Zooplankton density** $\#/m^3$	Mean	2.79×10^5	1.94×10^5	1.34×10^6	1.31×10^6	3.26×10^5	6.92×10^5	2.86×10^5
	N	9	9	9	8	7	9	9
	Min	1.6×10^4	2.2×10^4	5.5×10^5	6.8×10^4	5.7×10^4	7.4×10^4	2.9×10^4
	Max	8.9×10^5	6.2×10^5	3.1×10^6	5.1×10^6	6.8×10^5	2.8×10^6	9.8×10^5

* ACB-5 and ACB-8 are located 2.3 km and 6.4 km, respectively, from the confluence with the river.

** Zooplankton sampling began in January 1980.

stations, was relatively scarce at Matthews Bend stations.

29. Particulate organic matter (POM) samples were collected monthly and were partitioned into algal, zooplankton, and detrital components. Overall, main channel stations had the greatest detrital component and the least algal and zooplankton components; the reverse occurred at Matthews Bend's stations (see Sabol, Winfield, and Toczydlowski 1984). Detrital POM at main channel stations made up over 80 percent of the total POM for all samples except those in August (when algal POM was greater than half the total POM). At Matthews Bend stations algal POM contributed over 20 percent of the total for all samples except during the April flooding and at one of the Matthews Bend sampling sites in July. At the temporary secondary channel and Lower Cracraft Dike Field stations total POM was greatest during lotic periods with compositions resembling the main channel; under lentic conditions total POM was generally lower and consisted of greater parts of algal and zooplankton POM.

Low water sampling phase:
physical, chemical, and biological

30. The presence or absence of current was a major factor affecting water quality characteristics during the low water sampling phase. During this low river stage lentic conditions prevailed in Matthews Bend and in all three of the dike fields, with the exception of pool 3 of Chicot Landing Dike Field. These lentic habitats had many similarities as did the main channel, American Cutoff, and pool 3 of Chicot Landing Dike Field (lotic areas during the low water period). Major differences in turbidity and water transparency were observed among the habitats due to the presence or absence of current (Table 6). The lowest mean turbidity values were found in Lower Cracraft Dike Field (7 NTU), while the highest were found at American Cutoff (60 NTU) and pool 3 of Chicot Landing (60 NTU). Mean Secchi disk values for the various habitats ranked in an order which was the inverse of turbidity values, i.e. the greatest mean Secchi depth was at Lower Cracraft Dike Field (55 cm) with the lowest means at American Cutoff (17 cm) and pool 3 of Chicot Landing Dike Field (17 cm).

Table 6

Mean Surface Water Quality Variables, by Habitat, Sampled During the Low Water Study Period, 10-17 September 1980*

Variable	Habitat: Main Channel	American Cutoff	Chicot Landing Dike Field (lotic portion)	Chicot Landing Dike Field (lentic portion)	Leota Dike Field	Lower Cracraft Dike Field	Matthews Bend
Temperature, °C	28.0^{bc}	27.8^{bc}	27.1^{c}	26.9^{c}	29.0^{b}	31.0^{a}	30.5^{a}
Dissolved oxygen, mg/ℓ	6.7^{cb}	6.1^{cb}	6.3^{cb}	6.9^{cb}	9.1^{b}	15.8^{a}	13.7^{a}
Percent oxygen saturation	84^{bc}	79^{c}	77^{c}	85^{bc}	118^{b}	211^{a}	180^{a}
pH	8.0^{b}	8.0^{b}	7.8^{a}	7.8^{a}	8.2^{bc}	8.7^{d}	8.3^{c}
Secchi disk depth, cm	25^{c}	17^{d}	17^{d}	29^{c}	39^{c}	55^{a}	38^{b}
Turbidity, NTU	23^{bc}	60^{a}	60^{a}	23^{bc}	17^{c}	7^{d}	15^{cd}
Chlorophyll _a_, mg/m^{3}	21.4^{c}	15.7^{c}	15.8^{c}	130.6f^{a}	68.2^{b}	85.7^{b}	160.8^{a}
Total alkalinity, mg/ℓ as $CaCO_3$	160^{c}	125^{c}	123^{c}	365^{a}	159^{c}	163^{c}	233^{b}
Dissolved solids, mg/ℓ	286.0^{cd}	273.3^{cd}	292.5^{c}	447.5^{a}	293.3^{c}	263.9^{d}	361.0^{b}
Specific conductance, μmhos/cm	473^{cd}	460^{cd}	465^{cd}	718^{a}	496^{bc}	453^{d}	532^{b}
Suspended solids, mg/ℓ	80.3^{b}	125.7^{a}	155.4^{a}	32.9^{c}	42.1^{c}	23.7^{c}	53.3^{bc}
POM,** mg/ℓ	9.0^{b}	9.3^{b}	11.6^{b}	11.7^{b}	12.1^{b}	11.2^{b}	16.2^{a}
DOM,† mg/ℓ	47.1^{c}	45.0^{c}	62.9^{b}	77.9^{a}	45.3^{c}	41.9^{c}	51.8^{bc}
NO_2 + NO_3, mg N/ℓ	1.270^{a}	1.250^{a}	1.130^{a}	0.012^{c}	0.013^{c}	0.220^{b}	0.120^{bc}
NH_3, mg N/ℓ	0.048^{ab}	0.047^{ab}	0.010^{b}	0.013^{b}	0.063^{ab}	0.070^{ab}	0.125^{a}
Total phosphorus, mg P/ℓ	0.23^{ab}	0.27^{a}	0.27^{a}	0.13^{cd}	0.18^{bc}	0.11^{d}	0.19^{abc}
Dissolved orthophosphate, mg P/ℓ	0.083^{a}	0.086^{a}	0.082^{a}	0.012^{b}	0.011^{b}	0.011^{b}	0.014^{b}

* Means followed by different letters are significantly ($P \le 0.05$) different (Duncan's multiple range test).
** POM = particulate organic matter.
† DOM = dissolved organic matter.

31. Dissolved oxygen concentrations of surface waters were greatest in Lower Cracraft Dike Field, Matthews Bend, and Leota Dike Field. Supersaturation was common at these habitats with mean values of percent oxygen saturation equal to 211, 180, and 118 percent, respectively (Table 6). Saturation values were less than 100 percent at all other habitats.

32. Nitrite-nitrate nitrogen values were significantly ($P \leq 0.05$) higher in the lotic habitats during the low water phase (Table 6). Main channel stations were highest with a mean of 1.27 mg/ℓ, followed by American Cutoff (1.25 mg/ℓ) and Chicot Landing Dike Field (lotic portion) with a mean of 1.13 mg/ℓ. Total phosphorus and dissolved orthophosphate values were also highest for lotic habitats (main channel, American Cutoff, pool 3 of Chicot Landing Dike Field) and lowest for lentic habitats (all other dike fields and Matthews Bend) (Table 6).

33. The very high concentrations of chlorophyll a found in Matthews Bend ($\bar{x}$ = 160.8 mg/m^3) and the lentic portion of Chicot Landing Dike Field ($\bar{x}$ = 130.6 mg/m^3) were significantly greater ($P \leq 0.05$) than that of the other habitats (Table 6). While the pools of Leota and Lower Cracraft Dike Fields had intermediate mean chlorophyll a values ($\bar{x}$ = 68.2 and 85.7 mg/m^3, respectively), the lotic habitats had consistently low values (main channel $\bar{x}$ = 21.4 mg/m^3; permanent secondary channel $\bar{x}$ = 15.7 mg/m^3; and the lotic portion of Chicot Landing Dike Field $\bar{x}$ = 15.8 mg/m^3).

Discussion

34. The major water quality differences observed among the habitats are summarized in Figure 8; these differences were related to the presence or absence of current. The continual flowing conditions present in the main channel, along with the accompanying high turbulence, resulted in sustained high suspended solids concentrations at the main channel sampling stations (Table 2). The high suspended solids concentrations resulted in high turbidities and low water transparencies (low Secchi disk values) (Table 2), and, as a consequence, low light

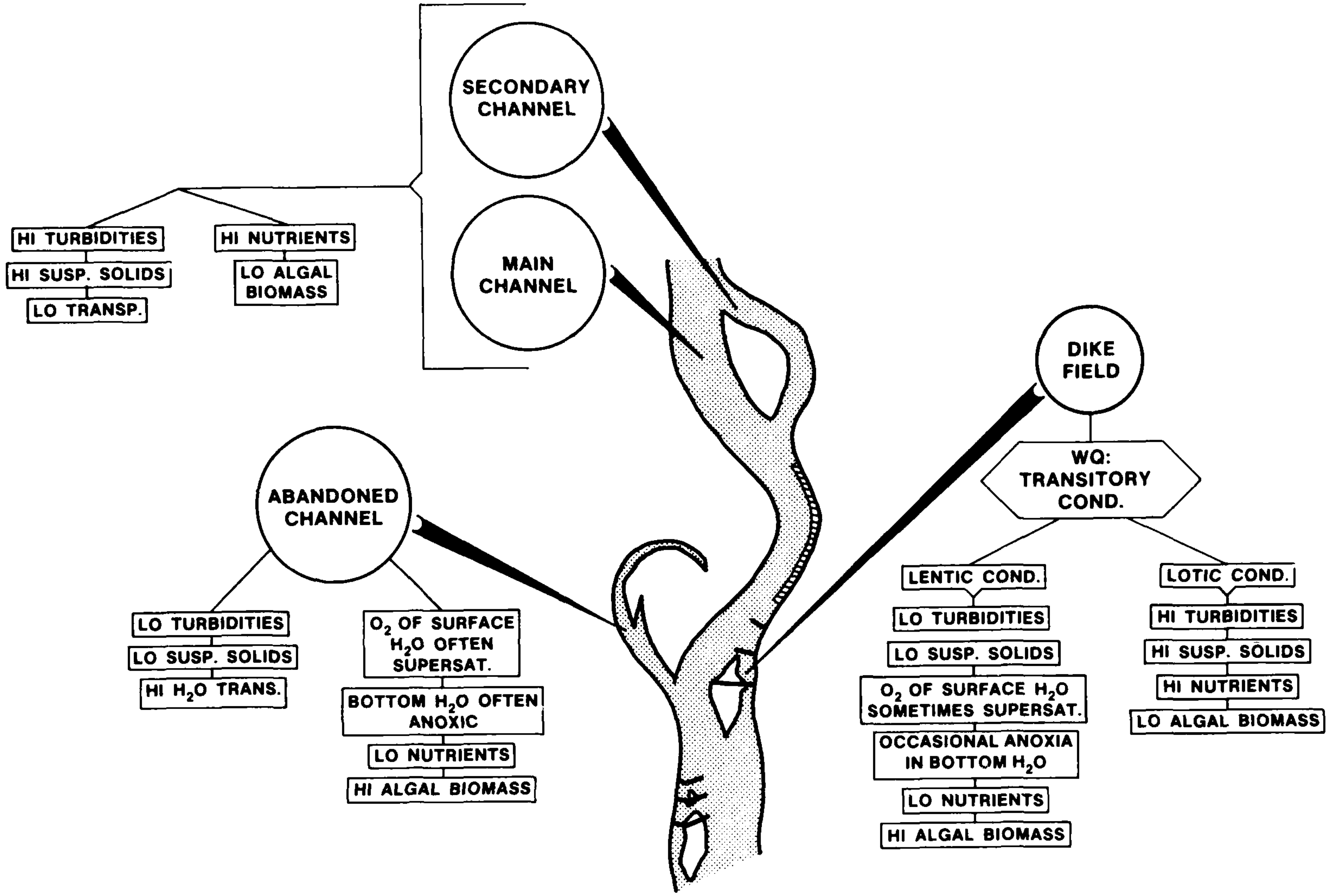


Figure 8. Schematic drawing of water quality conditions in lower Mississippi River habitats

penetration. These physical properties of the main channel had important biological and chemical ramifications. The low light penetration resulted in a very shallow photic zone which acted to retard primary production. Consequently, algal biomass (as reflected by chlorophyll a concentrations) was always low in the main channel (Figure 7). Reduced primary production resulted in generally lower and more stable pH and oxygen saturation levels (Table 3). And, since light seemed to be the limiting factor for primary production, nutrients such as nitrates and phosphates were always available in the main channel (Table 4). Hater (1975) saw similar effects in a study of primary production in the Ohio River. During fairly high flows the Ohio is in an open river state, i.e. gates at its dams are pulled out of the water and the river flows unimpeded. At these times water transparency is markedly reduced, primary production is low, and in vitro additions of nutrients to river water do not enhance primary production; i.e. the system is light limited rather than nutrient limited (Hater 1975). Our data indicate that the lower Mississippi River main channel operates similarly. Sampling in the other Mississippi River lotic areas, the permanent secondary channel, the third pool of Chicot Dike Field, and Kentucky Bend Chute (when it had water flowing through it), showed the measured physical, chemical, and biological parameters of these habitats to be close to that of the main channel.

35. During the flood conditions in April, physical, chemical, and biological parameters in the abandoned channel (Matthews Bend) were similar to that of the main channel. At all other times, however, water quality conditions in Matthews Bend were markedly dissimilar from that of the lotic habitats. Suspended solids were comparatively low in Matthews Bend, averaging less than a third of the mean of the main channel, and water clarity (as indicated by turbidity and Secchi disk depths) was therefore much greater (Table 2). This comparatively high water clarity results in enhanced primary production; Matthews Bend surface waters contained the greatest level of algal biomass (as indicated by chlorophyll a) among all the habitats studied with mean chlorophyll a concentrations over three times that of the main channel (Table 5,

Figure 7). This high primary production resulted in increased secondary production as zooplankton numbers in Matthews Bend averaged almost an order of magnitude greater than in the main channel (Table 5).

36. The high primary production in the lentic waters of the abandoned channel was the causal factor in a number of chemical differences apparent between Matthews Bend and the lotic sampling areas. While free-CO_2 was always detected in the main channel, it was only present during approximately one-half of the monthly samplings at Matthews Bend (Table 3). This is most probably due to algal uptake of CO_2 for photosynthesis. As CO_2 is taken out of solution for photosynthesis, pH concomitantly rises; this was shown by the relatively high pH readings made in Matthews Bend (Table 3). The high production was also indicated by the occurrence of dissolved oxygen supersaturation and high dissolved oxygen concentrations (e.g. a value of 23.2 mg O_2/ℓ) in the abandoned channel. The lower nutrient levels in this lentic habitat (Tables 4 and 6) were probably the result of increased water clarity, which resulted in increased primary production, thereby causing an increased utilization of nutrients. In addition, an increased algal standing crop is enhanced by the lack of current and the resulting increased retention time in this system. These lentic conditions have resulted in thermal stratification over much of the year, while the combination of lentic and eutrophic conditions has resulted in anoxia in the bottom waters of Matthews Bend over the summer.

37. Water quality conditions in the dike fields are of a transitory nature. When lotic conditions prevailed, the water quality values in the monthly samples at Lower Cracraft Dike Field were very similar to those of the main channel (Tables 2, 3, and 6). When lentic conditions were observed in the dike fields, suspended solids and water clarity tended to resemble Matthews Bend. As at Matthews Bend, increased water clarity resulted in relatively high algal biomass, which then caused high pH levels, high daytime surface dissolved oxygen concentrations, and low nutrient levels. In the Ohio River, Hater (1975) found that during low flows, when the river is impounded, reduced current velocities cause suspended solids to settle out, thereby markedly increasing

the depth of the river's photic zone. This then causes a dramatic increase in the river's primary production. Similarly, in the upper Mississippi River, Galtsoff (1924) and Platner (1946) found that under the lentic conditions associated with natural backwaters or impoundments, riverine waters undergo a rapid change in water quality conditions and become plankton rich.

38. Habitats such as abandoned channels and man-made dike fields add to the physical, chemical, and biological diversity of the lower Mississippi River ecosystem. In addition to increased overall diversity, these habitats, under lentic conditions, contribute to increased primary and secondary productivity, which is undoubtedly beneficial to the riverine ecosystem.

PART IV: BENTHIC MACROINVERTEBRATES

Introduction

39. Lower Mississippi River benthic macroinvertebrate studies conducted in the EWQOS program have included:

- a. A June 1978 pilot study of various aquatic habitats (river miles 480-530) (Mathis et al. 1981).
- b. A 1979-1980 study (river miles 506-566) of macroinvertebrate distribution in four of these habitats over high flow (flood stage), moderate, and low flow conditions (Beckett et al. 1983).
- c. A 1979 study of the macroinvertebrate communities on Corps-constructed stone dikes (Mathis, Bingham, and Sanders 1982).
- d. A June 1978 investigation of invertebrate drift (Bingham, Cobb, and Magoun 1980).

River habitats sampled in the pilot study included dike fields, natural (nonrevetted) and revetted banks, a permanent and a temporary secondary channel, the main channel, a sandbar, abandoned channels, and the dike structures themselves. This pilot study was conducted at a moderate river stage between 19 and 27 June 1978 (river stage at 15.6-19.4 ft). All samples were collected using either a Shipek or Petite Ponar grab sampler, with the exception of the dike structures, which were sampled by brushing organisms off hand-picked rocks into a collecting sieve. Macroinvertebrates from both grab and dike rock samples were sieved using a US Standard No. 35 mesh screen (openings = 500 μ).

40. From information gathered in this pilot study, four habitat types were chosen for intensive study (Beckett et al. 1983) over a high flow episode (16 Apr-11 May 1979, river stage = 45.6-46.6 ft), two moderate flow conditions (19-29 Jun 1979, river stage = 22.3-29.5 ft; 18-28 Sept 1979, river stage = 17.1-24.9 ft), and two low flow conditions (5-29 Nov 1979, river stage = 12.5-23.0 ft; 9-17 Sept 1980, river stage = 9.5-11.2 ft) (Figure 2). Selected sampling areas included dike fields, a natural bank habitat, a secondary channel, and an abandoned channel. The particular natural bank, secondary channel, and abandoned

channel selected for study were all sites which were fairly typical of such habitats in the lower Mississippi River. Three dike fields were chosen for study due to the physical heterogeneity exhibited among the dike fields (e.g. dikes notched vs. un-notched, deep vs. shallow dike field pools, occurrence of pool isolation at different river stages, etc.). Samples were again collected using either a Shipek or Petite Ponar grab sampler. The specific objectives of this intensive study included: (a) characterizing and comparing the various habitats in terms of their macroinvertebrate composition and densities, and (b) determining to what degree the habitats' species compositions change with variations in river discharge.

41. The 1978 pilot study indicated that the dike structures were colonized by productive, diverse invertebrate communities. To further investigate macroinvertebrate distribution on the dikes, rock-basket samplers were implanted in various positions on a stone dike in Lower Cracraft Dike Field during a period (21-22 February 1979) when large portions of the dike were emergent. With rising river stage water soon covered the rock-baskets; samples were then retrieved during 28-30 June 1979 after approximately 4 months of inundation. The 2-day drift study was conducted in June 1979 in the river's main channel. During this sampling surface tows were taken with conical plankton nets at five intervals over the 24-hr period.

Results

42. The 1979-1980 intensive study (Beckett et al. 1983) showed that the biotas present in the natural bank, the secondary channel, and the abandoned channel remained dissimilar from each other for all flow regimes (Figure 9). Substrates in Anconia Natural Bank consisted either of sand or clay, with clay predominant (Figure 10). These clay substrates in the natural bank were dominated over all river stages by the burrowing mayflies *Tortopus incertus* and *Pentagenia vittigera* (Figure 9). Both *T. incertus* and *P. vittigera* have been described as being fairly specific in habitat preference, selecting clay banks of large

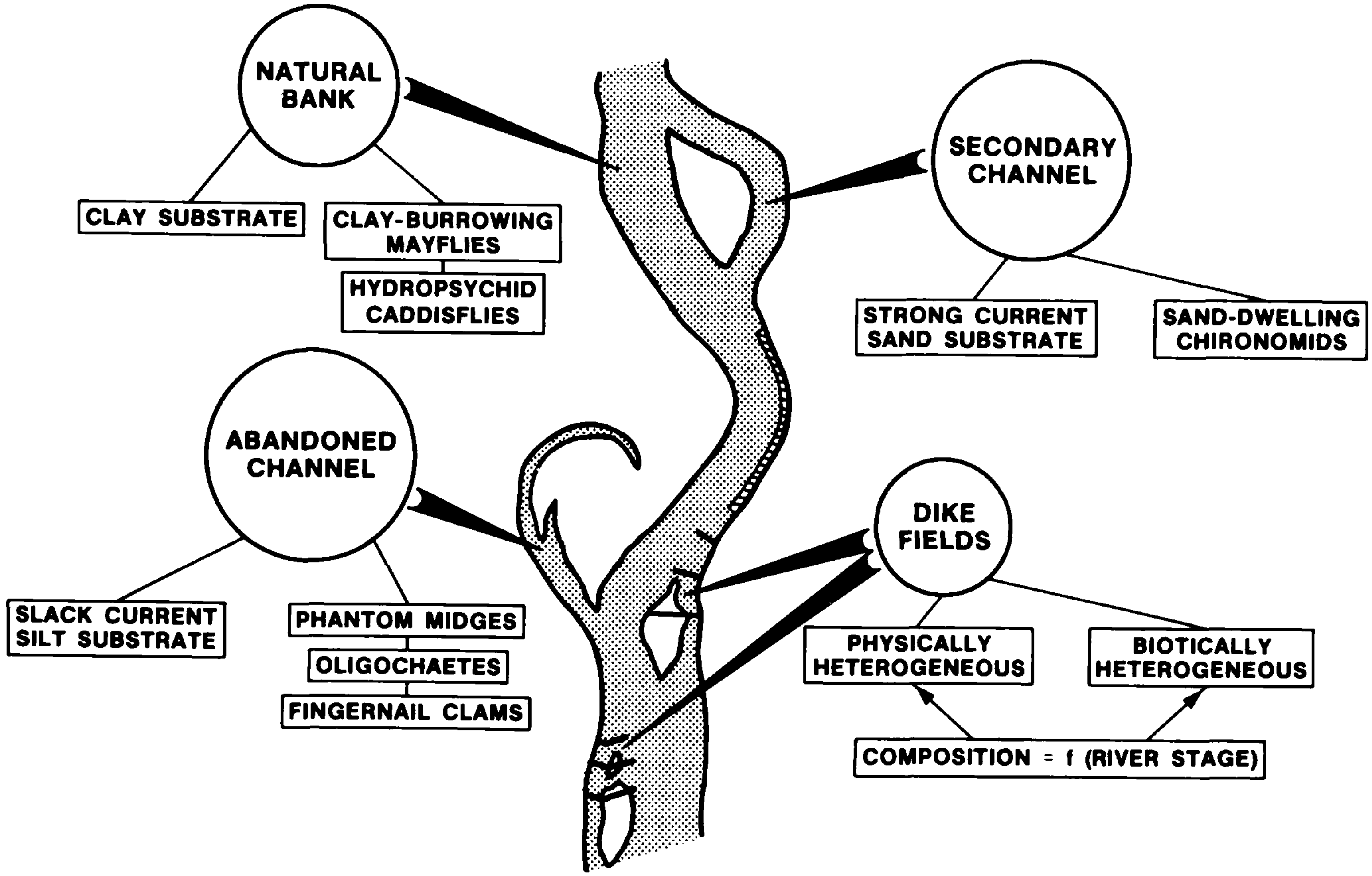


Figure 9. Schematic drawing of the lower Mississippi River showing existent physical conditions and the most common macroinvertebrates in the investigated habitats. The physical and biotic heterogeneity exhibited by the dike field is largely a function (f) of seasonal changes in river stages

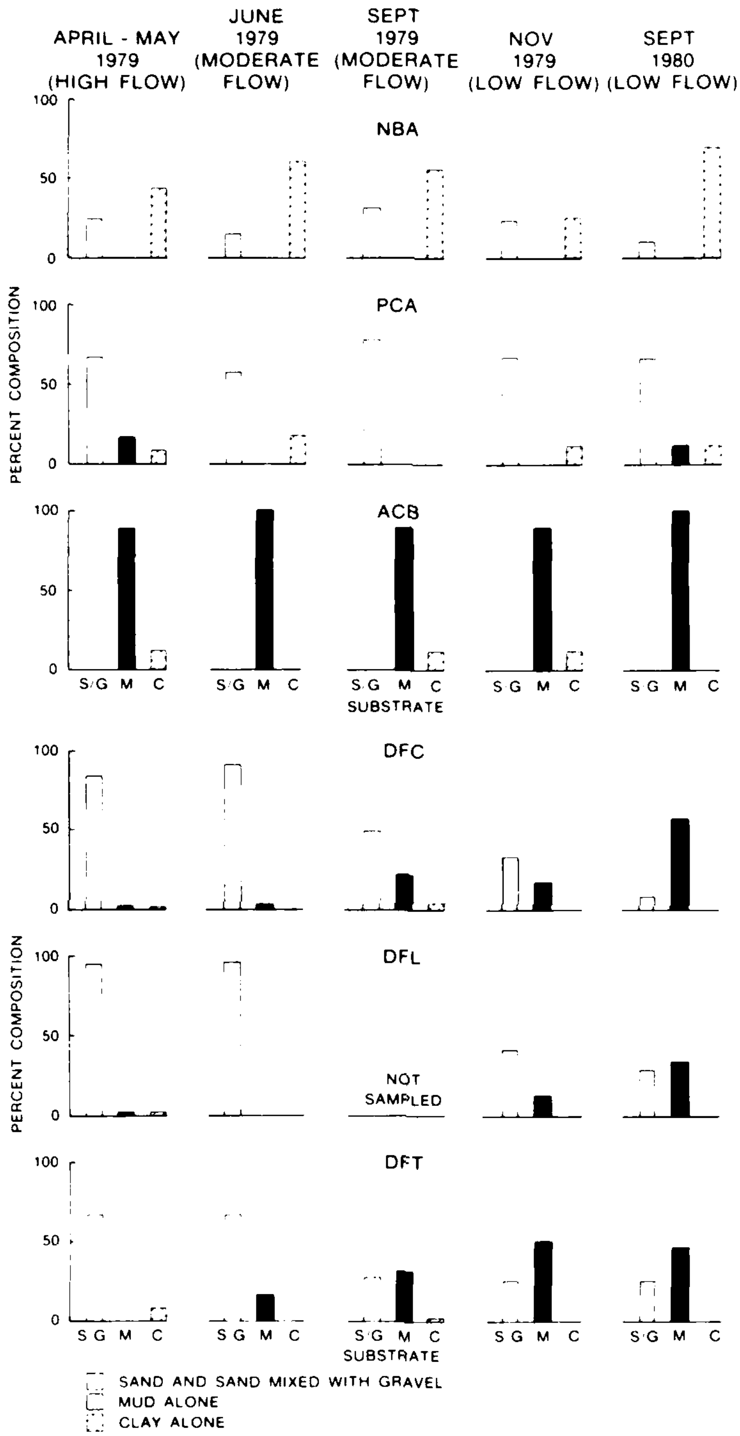


Figure 10. Percent composition of bottom substrates for 1979-1980 study site samplings. Only the three dominant substrate types are shown. NBA = natural bank - Anconia; PCA = American Cutoff (permanent secondary channel); ACB = abandoned channel - Matthews Bend; DFC = Lower Cracraft Dike Field; DFL = Leota Dike Field; DFT = Chicot Landing Dike Field

rivers in which to burrow (Edmunds, Jensen, and Berner 1976). Clay banks on the lower Mississippi River often have a characteristic honeycombed appearance with the bank surfaces distinguished by the very large numbers of holes resulting from the burrowing activities of these species. Hydropsychid caddisflies (*Hydropsyche orris* and *Potamyia flava*) were also fairly common in the samples taken at Anconia Natural Bank. These larvae colonized the submerged tree branches which were common in this habitat; the caddisfly larvae were often collected in the Shipek as a result of being scraped off the branches by the sampler during its descent or by having small branches snapped off submerged trees by the sampler. The pilot study (Mathis et al. 1981) results in regard to the natural bank habitat agree closely with those of the intensive study. In their investigation of five natural banks Mathis et al. (1981) consistently found *T. incertus* and *P. vittigera* to be the "numerically codominant infaunal organisms...in the natural bank bottom sediments, reaching their greatest densities within the cohesive clay sediments." As in the intensive study, Mathis et al. (1981) also found *H. orris* and *P. flava* to be quite abundant on the submerged trees and branches along the natural banks.

43. The permanent secondary channel (American Cutoff) had a predominantly erosional substrate (sand) (Figure 10) with fairly strong currents through the habitat at all river stages. Not surprisingly, macroinvertebrate densities were quite low in this habitat (Beckett et al. 1983). Mathis et al. (1981) found the same site to be "unproductive" in the 1978 pilot study, and Hynes (1970) has indicated that in lotic systems sand is a rather poor habitat with "few specimens of few species." The 1979-1980 study (Beckett et al. 1983) showed, however, that such areas do possess a very distinct assemblage of organisms, consisting of two sand-dwelling chironomid species, *Chernovskiia orbicus* and *Robackia claviger*. *Chernovskiia orbicus* has been reported from sandy areas of large rivers in the Soviet Union and the United States while *R. claviger* has been collected from a number of rivers in the United States, including the Mississippi and Missouri (Saether 1977). The sandy areas (the predominant substrate type) of the secondary

channel are consistently dominated by one or both of these chronomid species. Interestingly, the high current, sandy-substrate areas of the dike fields were also colonized by these chironomids (Figure 11). It is apparent, therefore, that in the Mississippi River these species are found only in patches of sand or sand mixed with gravel, usually in an area of strong current.

44. The abandoned channel habitats are characterized by slack currents and uniformly silty substrates (Mathis et al. 1981). Although some current moved through the abandoned channel (Matthews Bend) at flood stage in April 1979, the bottom substrate still consisted almost entirely of mud (silt). The biota in the abandoned channel presented a marked contrast to that of the unproductive permanent secondary channel, both in terms of dominant taxa and total densities (Figure 9, see also Beckett et al. 1983). The 1979-1980 study showed that macroinvertebrate densities were high in the abandoned channel at all river stages.

45. The dominant taxon over both the intensive study in Matthews Bend and the moderate flow investigation of five abandoned channels (Mathis et al. 1981) was the phantom midge *Chaoborus punctipennis*. Although present in riverine habitats (Whitton 1975), phantom midges are found in greater abundances in lentic habitats such as lakes and ponds (Cole 1975, Merritt and Schlinger 1978, Pennak 1978, Reid 1961), and are especially common in eutrophic lake and pond bottoms (Cole 1975, Reid 1961). Pronounced oxygen depletion which occurred in 1978 near the bottom of two comparatively deep abandoned channels (mean bottom dissolved oxygen = 1.1 mg/ℓ at Matthews Bend and 1.8 mg/ℓ at Lake Lee; Mathis et al. 1981) and at Matthews Bend in the summer of 1980 (Sabol, Winfield, and Toczydlowski 1984) apparently did not inhibit colonization of the bottom by large numbers of *Chaoborus*. *Chaoborus* have been known to survive 2 to 3 weeks in anaerobic conditions (Cole 1975) and are therefore adapted to such eutrophic conditions.

46. In addition to *Chaoborus*, large numbers of tubificid oligochaetes and fingernail clams were collected from the abandoned channels in both the pilot study and the intensive study. Reid (1961) described the profundal fauna of eutrophic lakes as consisting of "predominantly

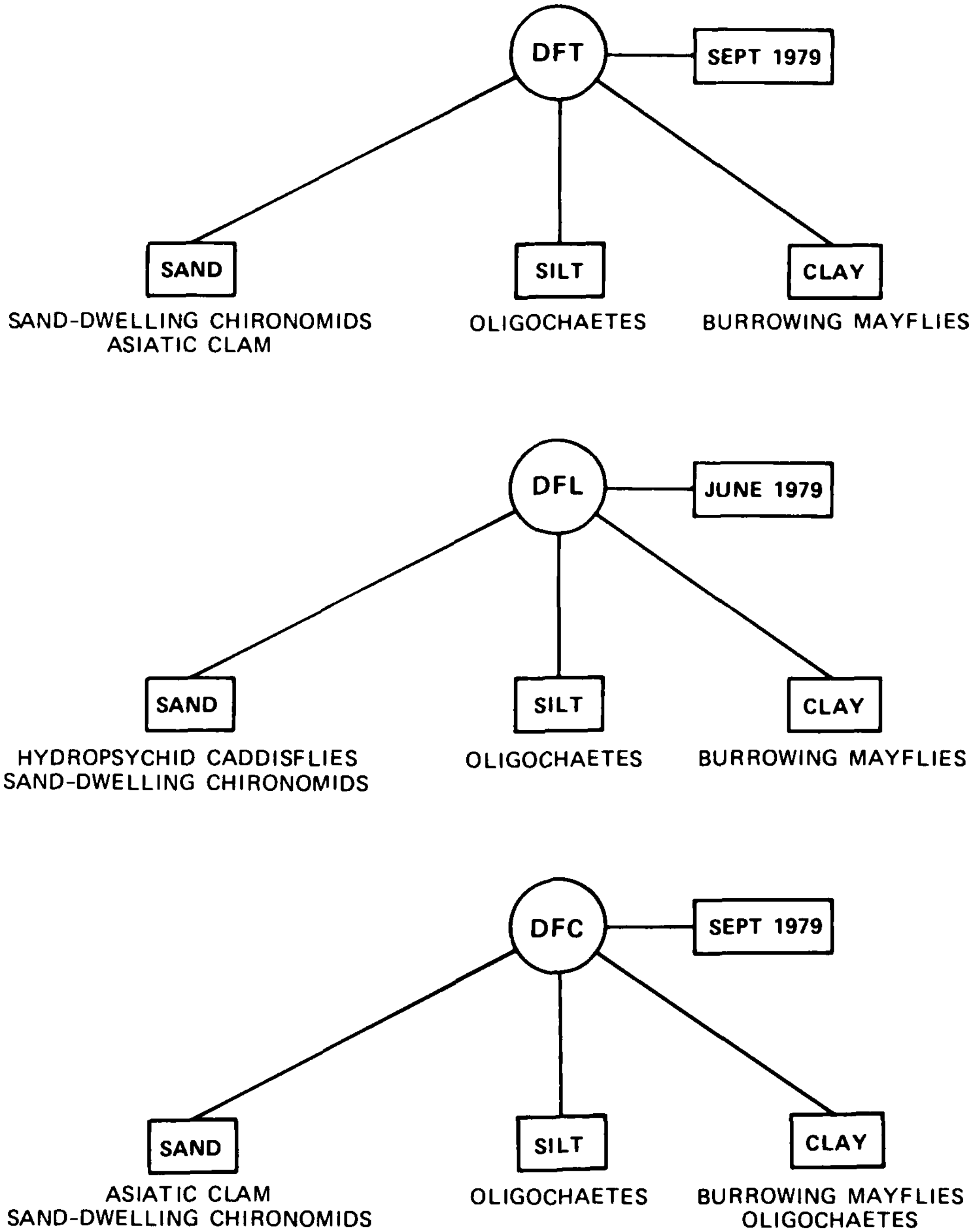


Figure 11. Schematic of dike fields showing the most common macroinvertebrates in each of the major substrates present. The dates of the invertebrate samplings are also shown. September and June 1979 sampling periods were both during moderate river flows. DFT = Chicot Landing Dike Field; DFL = Leota Dike Field; DFC = Lower Cracraft Dike Field

tubificid oligochaetes, bivalved mollusks of the family Sphaeriidae and dipteran insects of the genus *Chaoborus* and *Chironomus*." It is apparent that the biota in the abandoned channels closely fits this description. Species such as *R. claviger*, *C. orbicus*, *P. flava*, *T. incertus*, and *P. vittigera*, which were commonly collected from the various flowing water habitats during the 1979-1980 study, were never collected at Matthews Bend throughout the same study period (and only a single individual of *Hydropsyche* sp. was collected) (Beckett et al. 1983). The biota in the abandoned channels is therefore clearly of a more lentic, than lotic nature.

47. The sediments of the dike fields are mosaic-like, consisting of patches of various sediment types arranged as a function of current across the habitat (Figure 12). The importance of substrate to invertebrate distribution in the lower Mississippi River is shown by the concomitance of this mosaic-like substrate pattern and the distributional pattern of macroinvertebrates. Within the dike fields, sand and gravel areas were colonized by the Asiatic clam *Corbicula fluminea* and the chironomids *C. orbicus* and *R. claviger* (i.e. similar in composition to the macroinvertebrates of American Cutoff); mud substrates were dominated by *Limnodrilus* spp. (Oligochaeta) and *C. punctipennis* (i.e. similar in composition to the community at Matthews Bend); and clay substrates were colonized by the burrowing mayflies *T. incertus* and *P. vittigera* with some hydropsychid caddisflies present on additional substrates in the clay (i.e. similar to the community at Anconia Natural Bank) (Figures 9 and 11). The dike fields are therefore physically and biotically heterogeneous and serve as "integrators" of biotas that could be found elsewhere in the river only by collecting over a number of different habitats.

48. A species of special interest was the burrowing mayfly *Hexagenia* sp. (*Hexagenia* sp. discussed in this report refers to *H. limbata* and/or *H. bilineata*; characters used to differentiate these two species at the nymphal stage have proved to be unreliable; Edmunds, Jensen, and Berner 1976). Fremling (1973) has stated that *Hexagenia* densities are much higher in the upper Mississippi River than in the

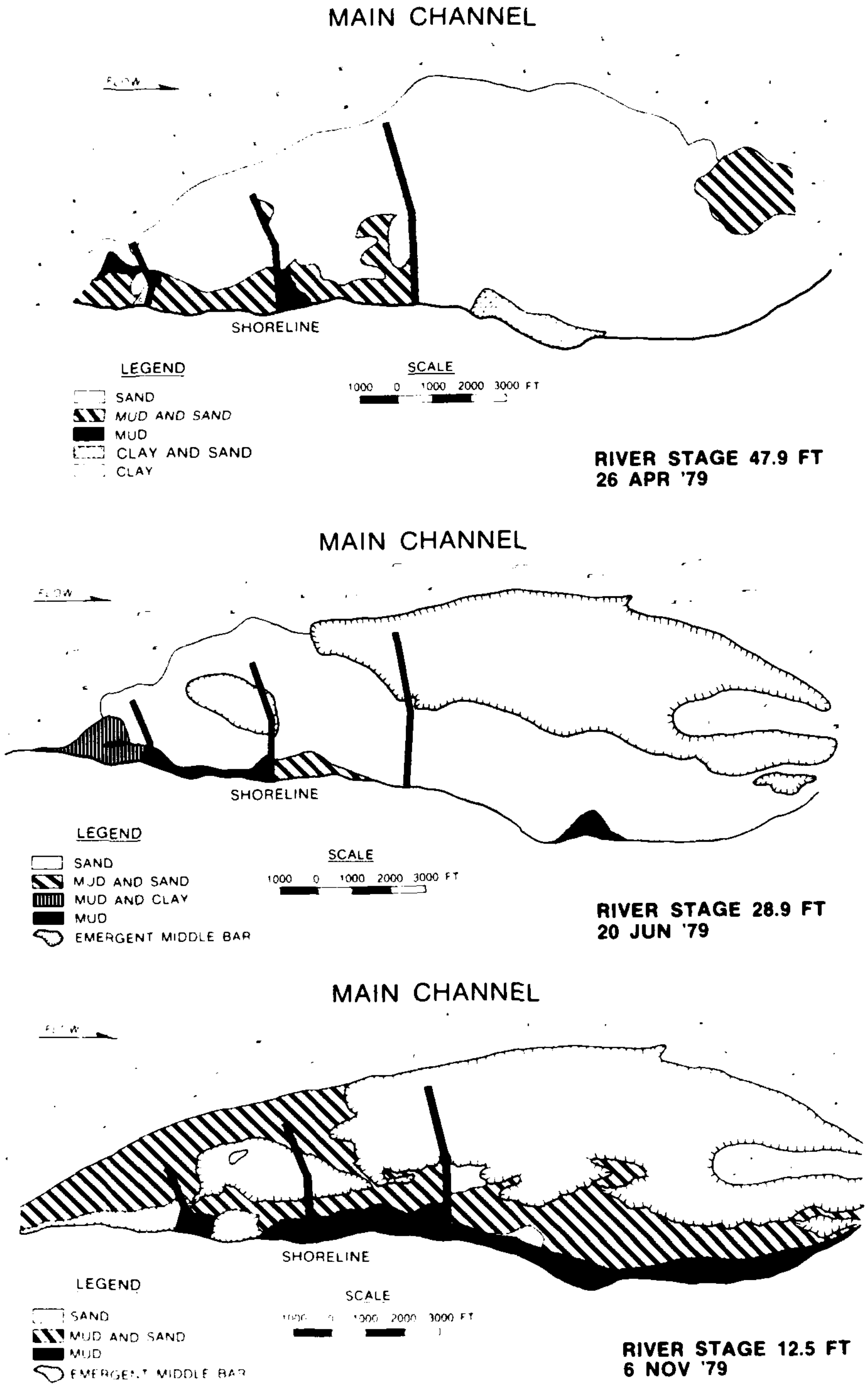


Figure 12. Substrate map of Lower Cracraft Dike Field at high, moderate, and low river stages

lower Mississippi River, and has attributed this, in part, to the channelization of the lower Mississippi River through the use of levees, dikes, and revetments. It is apparent, however, that the mud substrates of the dike fields in our study area supported fairly dense *Hexagenia* populations. *Hexagenia* sp. was the third most common macroinvertebrate in the mud substrates of Chicot Landing Dike Field in September and November 1979 ($\bar{x}$ = 135 individuals/m^2 and 157 individuals/m^2, respectively), and at Lower Cracraft Dike Field *Hexagenia* sp. was the second most abundant species in the mud substrates in November 1979 ($\bar{x}$ = 124 individuals/m^2) and the third most common taxon in September 1979 ($\bar{x}$ = 51 individuals/m^2). Therefore, although dikes are part of the channelization process, they also create habitat areas suitable for *Hexagenia*.

49. Substrate composition at the natural bank, the permanent secondary channel, and the abandoned channel remained fairly constant over all river stages (Figure 10), and the benthos at these habitats experienced only minor changes in composition over the various flow regimes. In each of the dike fields, however, substrate dominance changed from an erosional substrate (sand) to a depositional substrate (mud) with decreasing river stage (Figure 10). Paralleling these changes in substrate composition were large alterations in biotic composition. At high river flows the dike structures and middle bars were submerged, and strong currents moved through the dike fields resulting in a predominantly sandy substrate at all the dike fields. These sandy areas were colonized by sparse populations of sand-dwelling chironomids and oligochaetes (Beckett et al. 1983). At moderate flows large middle bar areas were emergent, the top of the dikes were near the river's surface, and currents through the dike field, though fairly strong, had moderated from those of the high flow conditions. The dike fields were biotically diverse during moderate flows, as depicted in Figure 11. At low flows many of the dike fields became largely a series of isolated slack-water pools, being circumscribed by the emergent dikes, the shore, and large middle bar areas. At this low river stage substrate composition in the dike field pools showed a marked shift with silt substrate

areas showing greater development and deposition of a fine layer of silt on top of what had previously been clean sand areas (Figure 10, see also mud and sand development in Figure 12). At this point physical conditions (slack-water, silt substrate) approximated conditions in the abandoned channel and the biota responded accordingly with a lentic assemblage of organisms (*Limnodrilus* spp., *Ilyodrilus templetoni*, *C. punctipennis*, and *Tanypus* sp.) present in relatively dense populations in the mud substrates (Beckett et al. 1983).

50. Two other examples of the close interaction of invertebrate distribution and substrate conditions in the lower Mississippi River are apparent from a close examination of macroinvertebrate distributions at low flow in the Chicot Landing and Leota Dike Fields. A notch in the third dike at Chicot Landing has resulted in water flow and a strong current in pool 3 of the dike field, even at low flow. This has produced a sand and gravel substrate downstream of the notch. This area was colonized by the sand-dwelling chironomid *R. claviger* and the Asiatic clam (Beckett et al. 1983); these organisms were the dominants in the sand-substrate, strong current conditions present in the permanent secondary channel at all river stages and in the sandy areas of the dike fields during moderate and high flows. At Leota Dike Field, the dikes are unnotched and the dike field became a series of isolated pools at low flow. *Limnodrilus* immatures were the dominant taxon in Leota's mud substrates at this time (Beckett et al. 1983). In contrast, Leota's sandy areas (which at low flow were basically sand with a fine overlying layer of silt) were dominated by the oligochaete *Aulodrilus pigueti*. Fomenko (1972) has shown *Limnodrilus hoffmeisteri* and *Limnodrilus claparedianus* to be most common in bottom substrates consisting of thick mud; *A. pigueti*, however, is most abundant in substrates consisting of "slightly or moderately muddy sand" (Fomenko 1972). It is apparent from these and other examples that invertebrate distribution in the Mississippi River habitats is largely a function of current and substrate conditions, with current velocity a controlling factor in determining the nature of the substrate. Wells and Demas (1979) arrived at a similar

conclusion following their investigation of macroinvertebrate distribution in the lower Mississippi River.

51. To this point the majority of macroinvertebrates discussed have been embenthic, occurring in (penetrating) the available substrates. However, the numerically dominant organisms on the rock dike structures are epibenthic (occurring on, but not penetrating their substrates). The net-spinning caddisfly *H. orris* was the most abundant taxon collected during the investigation of invertebrate composition on stone dikes (Figure 13) (Mathis, Bingham, and Sanders 1982), making up 60.1 percent of the organisms collected. Other common taxa, in order of abundance, were the tube-building chironomid *Rheotanytarsus* sp. (19.1 percent), the net-spinning caddisfly *P. flava* (8.4 percent), the chironomid *Polypedilum* sp. (5.1 percent), the isopod *Lirceus* (2.1 percent), and the mayfly *Baetis* sp. (0.9 percent).

52. Macroinvertebrate densities on the dikes were very high. In the 1979-1980 lower Mississippi River habitats study (Beckett et al. 1983), the abandoned channel consistently supported the highest macroinvertebrate densities. Mean macroinvertebrate densities in the mud substrates of the abandoned channel ranged from 3111.6 individuals/m^2 (September 1980) to 7243 individuals/m^2 (September 1979) (Beckett et al. 1983). In comparison, mean density on the dike structures was 101,968 individuals/m^2 of dike surface area (Mathis, Bingham, and Sanders 1982). Such extremely high densities are due to two factors: (a) colonization of the rock surfaces by dense populations of epibenthic organisms; and (b) the three-dimensional aspects of the dike structures, i.e., invertebrates on the dikes were observed colonizing the rocks deep into the interior of the dike while the river's embenthic organisms are confined to only a shallow zone near the river-substrate interface (Ford 1962). It is apparent that the dike structures are important to the lower Mississippi River ecosystem since they provide a hard, stable substrate which is densely colonized by epibenthic macroinvertebrates.

53. Macroinvertebrates on the dike structures, or in any of the other habitats, have two potential sources: (a) reproduction at a particular site with subsequent maturation at that same site; and

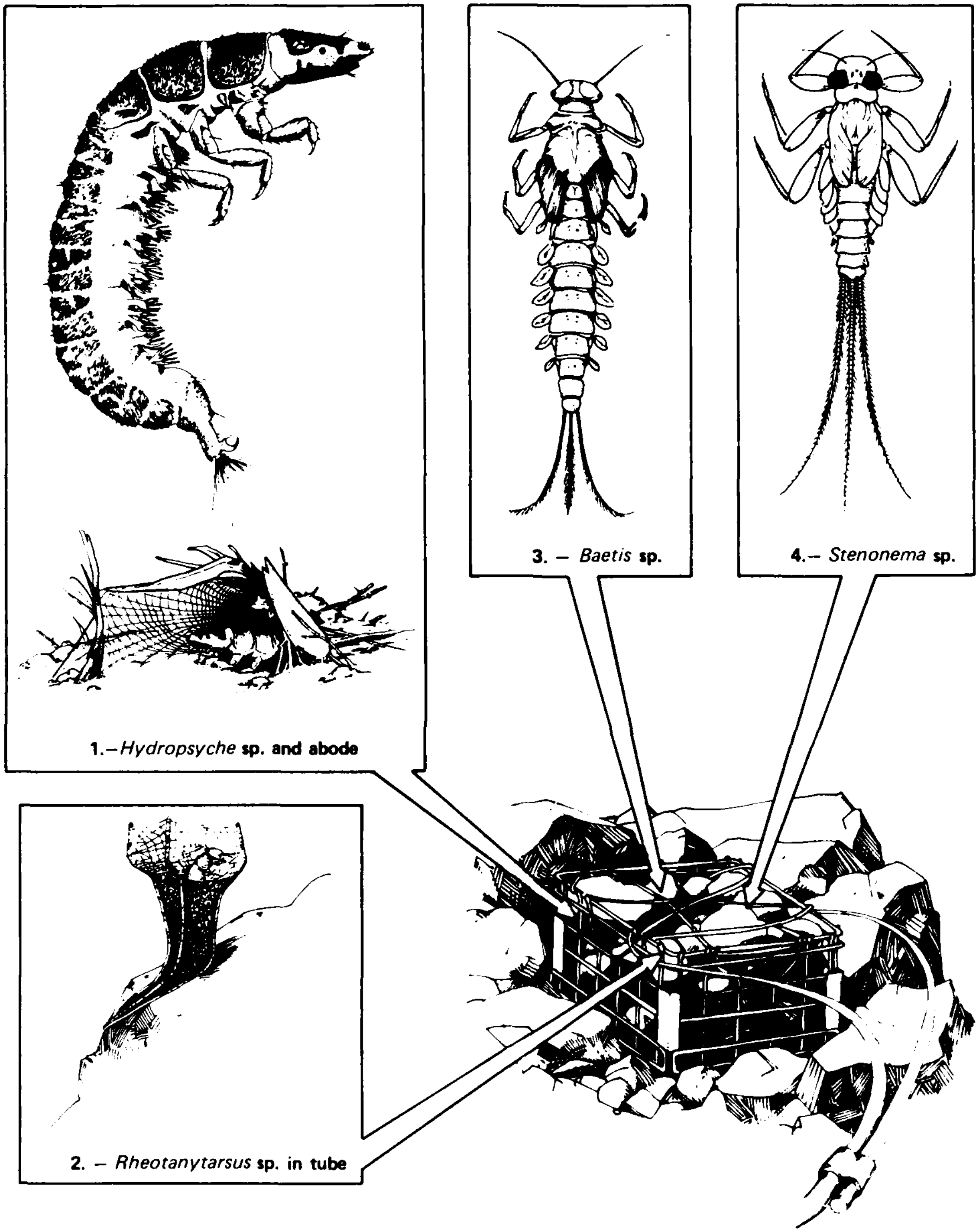


Figure 13. Illustration of rock-basket implant on the stone dikes; also shown are some of the more abundant macroinvertebrates collected from these samplers

(b) invertebrate colonization of an area by migration via small local movements or via drift. Invertebrate drift is an important colonization source in the lower Mississippi River. Bingham, Cobb, and Magoun (1980) estimated that the river transported a total of 1.5×10^9 macroinvertebrates in the drift past their sampling location in a 24-hr period from 27 to 28 June 1978. *Hydropsyche orris* (which was found in such high densities on the dike structures) was the most abundant taxon in the drift. Other abundant taxa in drift samples included the caddisfly *P. flava* (also commonly collected from the dike structures), the phantom midge *Chaoborus*, *Polypedilum* spp. (Diptera:Chironomidae), and the clay-burrowing mayflies *T. incertus* and *P. vittigera*.

54. Two habitats which were sampled in the macroinvertebrate pilot study, but not in the intensive study, were revetted banks and the main channel. The upper half or more of the revetted banks in the sampling areas consisted of articulated concrete mattress with no surficial sediment deposits (Mathis et al. 1981). Investigating these areas using benthic grabs proved to be ineffective as the grab sampler simply scraped the concrete surface and did not allow the collection of either qualitative or quantitative data. Effective sampling gears for the concrete mattress are presently being developed.

55. Although the main channel habitat constitutes a large portion of the total river area, the high current velocities and coarse sand substrates have precluded appreciable macroinvertebrate colonization. Mathis et al. (1981) collected a total of only nine organisms from 18 Shipek grabs in the main channel. Wells and Demas (1979), in another lower Mississippi River macroinvertebrate investigation, also found coarse substrate, high current velocity areas to be depauperate.

Discussion and Ecological Implications

56. The lower Mississippi River natural banks, consisting largely of clay substrates, are an optimal habitat for the large-river, burrowing mayflies *T. incertus* and *P. vittigera*. *Tortopus incertus* and *P. vittigera* are very specific in their habitat preferences, being found in

high densities only in clay substrate areas of large rivers (Edmunds, Jensen, and Berner 1976). These mayflies are large macroinvertebrates and contribute appreciable biomass to the Mississippi River ecosystem. The effect on these species resulting from the covering of the natural banks with revetment is unknown. Field observations have shown large numbers of mayfly burrows under buckled articulated concrete mattress. However, smooth, non-disrupted fields of concrete mattress may prevent colonization of the underlying clay substrate. The possible adverse environmental effects resulting from covering more of the natural bank habitat and/or altering current and substrate conditions in natural bank areas with dike structures should be considered in the design of revetments and dikes.

57. The dike fields proved to be areas of considerable physical and biotic heterogeneity at moderate and low flows (Figure 11). The dike fields' low flow, slack-water habitats were characterized by high macroinvertebrate densities and high species diversities, and also served as a habitat for species such as *Hexagenia* which require a depositional (mud) substrate.

58. The finding of high *Hexagenia* densities in the mud substrates of the dike fields is of considerable interest since: (a) *Hexagenia* is large in size and therefore contributes considerable biomass to the lower Mississippi River ecosystem; (b) under suitable conditions (high dissolved oxygen, mud substrate, slack currents) this taxon can be found in high densities (Fremling 1973, Riklik and Momot 1982); (c) it is utilized as food by a number of fish species (Hoopes 1960; Burress, Krieger, and Pennington 1982); and (d) Fremling (1973) has attributed the great reduction in the number of burrowing mayflies (*Hexagenia*) in the lower Mississippi River (in comparison to the upper Mississippi River) in part to Corps channelization practices. It seems probable that channelization of the lower Mississippi River has markedly reduced the amount of suitable *Hexagenia* habitat. It is also interesting to note, however, that the only place in the lower Mississippi River in which dense *Hexagenia* collections have been made is in the silt substrates of the dike fields. A comparison of *Hexagenia* abundances in the

dike fields to numbers found in other systems (Table 7) shows that the dike field mud substrates support fairly dense populations, especially in view of the fact that, unlike the lower Mississippi River, all the other systems are lentic. It is interesting, therefore, that although the dike fields and dikes are part of the channelization process, they also create habitat areas which are suitable for *Hexagenia*.

59. It is apparent that the dike fields, because of their biotic diversity and their depositional substrates at low river stages, are important habitats in the lower Mississippi. However, these beneficial effects are lost if, as in the case of the Missouri River, the dike fields accrete sand until they become terrestrial, rather than aquatic, habitats (Funk and Robinson 1974; Hallberg, Harbough, and Witinok 1979). Whether the lower Mississippi River's dike fields will have the same fate as those of the Missouri River is unknown at this time. Hopefully dike fields could be designed such that they would not completely fill in, i.e. at moderate to low river stages slack-water pools would form below the dikes. The use of permanent, deep, wide notches in the dikes, which results in a strong current in the pools both above and below the notched dikes, does not appear to be environmentally beneficial. The occurrence of such a notch in Chicot Landing Dike Field produced strong currents through the notch, which then produced a sandy substrate, which, in turn, was colonized only by a very depauperate fauna. The existence of such sandy areas has already been favored by the channelization practices.

60. Among the habitats investigated in the intensive study (natural bank, secondary channel, abandoned channel, and dike fields), the abandoned channel consistently supported the highest macroinvertebrate densities with approximately 3000 to 7500 individuals/m^2 (Beckett et al. 1983). These densities are small, however, when compared to the mean density of over 101,000 individuals/m^2 of dike surface, which was determined from the invertebrates collected on the dike at Lower Cracraft Dike Field (Mathis, Bingham, and Sanders 1982). Hall (1982) made a similar comparison for the upper Mississippi River, finding densities on the dikes there to be 26.5 times that of the macroinvertebrate densities

Table 7

Comparison of *Hexagenia* Densities in Lower Mississippi River Dike Field Mud Substrates with *Hexagenia* Abundances in Other North American Habitats*

Body of Water	Latitude	Area ha	Mean Depth m	Mean Density no./m²	Reference
Boomer Lake (reservoir), Oklahoma	36°07.1' N	3625	2.98	548	Craven and Brown (1969)
Tuttle Creek Reservoir, Kansas	39°11.0' N	6400	8.0	47	Horst and Marzolf (1975)
Bradenburg Pond (man-made), Ohio	39°30.0' N	0.61	1.5	473	Rutter and Wissing (1975)
Western Lake Erie	42°N	3.27×10^5	7.4	114[a] 19[b] 0[c]	Wood (1973)
Gun Lake, Michigan	42°36' N	1084.6	Several basins	258	Hunt (1953)
Pine Lake, Michigan	42°36' N	267.1	Several basins	234	Hunt (1953)
Lewis and Clark Reservoir, South Dakota	45°51.2' N	11331	4.9	182	Hudson and Swanson (1972)
Savanne Lake, Ontario	48°49.5' N	364.3	2.6	107	Riklik and Momot (1982)
Lake Winnipeg, Manitoba	52°N 51°N	2.37×10^6[d]	10.6	93[e] 62[f] 60[g]	Neave (1932) Flannagan (1979)
Lower Mississippi River:					
Chicot Landing Dike Field,					
Sep 1979:				135[h]	
Nov 1979:				157[h]	
Lower Mississippi River:					
Lower Cracraft Dike Field,					
Sep 1979:				51[h]	
Nov 1979:				124[h]	

* Table adapted from Riklik and Momot (1982).
a 1930.
b 1951.
c 1963.
d Total area.
e Narrows.
f South basin.
g Parts of south basin.
h Numbers are from mud substrate areas only.

in nearby bottom sediments. Beckett (1982) found very high *H. orris* densities in summer and autumn on rock-filled barbecue baskets placed in the Ohio River, with a mean of over 11,000 *H. orris*/basket (basket length = 250 mm, basket diameter = 166 mm) in early October. *Hydropsyche orris* was also the most abundant species collected from the stone dikes in the lower Mississippi River (Mathis, Bingham, and Sanders 1982); Fremling (1960) found high *H. orris* densities on solid substrates in areas of the upper Mississippi River in which a fairly strong current existed. Fremling (1960) and Benke and Wallace (1980) theorized that the principal limiting factor of hydropsychid caddisfly abundances in many large rivers was the availability of a solid, silt-free substrate in areas of ample current. The large numbers of hydropsychid caddiflies (*H. orris* and *P. flava*) on the dike structures, along with the large number of other macroinvertebrate species present, indicate that the dikes provide such a substrate in the lower Mississippi River. The presence of such abundant populations on these dikes is further reason to prevent the filling in of the dike field since, with sand accretion, the dike structures also become terrestrial and are no longer available as an aquatic habitat.

PART V: LARVAL FISHES

Introduction

61. The principal objective of the ichthyoplankton studies has been the description of larval fish composition and abundance among aquatic habitats of the lower Mississippi River. Such a description was generated from two EWQOS-sponsored studies. The first investigation (Schramm and Pennington 1981), conducted from 8 March to 13 November 1978, was a pilot study of larval fishes in nine lower Mississippi River habitats and took place within a 25-mile stretch of the lower Mississippi River (river mile 506-531). The study habitats included: (a) an abandoned channel, (b) an oxbow lake, (c) two natural banks, (d) four revetted banks, (e) five dike fields, (f) a sandbar, (g) a permanent secondary channel, (h) a temporary secondary channel, and (i) four main channel locations. Samples were collected from these habitats approximately every 2 weeks from March through August, and monthly during September, October, and November. Generally, each habitat was represented by a single sampling station from which duplicate samples were taken on each sampling date. The abandoned channel, oxbow lake, and Seven Oaks Dike Field each had two sampling stations. An ancillary investigation of diel periodicity in larval fish distribution was conducted at Sunnyside Revetment on 27-28 June 1978 (Schramm and Pennington 1981), with a number of replicate samples collected at midday (1141 to 1410 hr), afternoon (1530 to 1608 hr), dusk (2048 to 2150 hr), night (0100 to 0158 hr), and dawn (0515 to 0607 hr).

62. The second study of larval fish occurrence in the lower Mississippi River (Conner, Pennington, and Bosley 1983) was conducted from March through October 1980. Habitats sampled were located between river miles 505 and 525 (roughly the same area as the ichthyoplankton pilot study) and included: (a) two main channel locations, (b) a temporary secondary channel, (c) an abandoned channel, (d) two dike fields, and (e) two revetted banks. Two sampling stations were established at each location with the exception of the main channel areas, where one

sampling station was maintained at each location; duplicate samples were taken at each station on each sampling date. Samples were taken every 2 weeks over the March-October sampling period. Collection dates in 1980 coincided with those of the 1978 pilot study.

63. The larval fish pilot study showed that the dike fields supported a diverse ichtyoplankton community. Therefore, as part of the 1980 larval fish investigations a supplementary intensive sampling program was conducted in Lower Cracraft Dike Field (see Figure 14) over the March to October collection period. The objective of this particular study was to elucidate the important mechanisms controlling larval fish distribution, especially in the dike fields.

64. In both 1978 and 1980 ichthyoplankton samples were collected during the daytime with 505-μ mesh plankton nets towed in a downstream direction. Each pair of samples was taken simultaneously, one off the starboard side of the boat, the other off the port side. Nets were towed at 0.5 m below the surface for approximately 5 min. A flowmeter was mounted in the center of the mouth of each net to estimate the volume of water filtered. After collection samples were immediately fixed in formalin; larval fish were later identified to the lowest possible taxon.

65. The phenology (study of natural phenomena that occur periodically and their relation to changes in season) of larval fishes in the lower Mississippi River will be used as a basis for the presentation of results from the 1978 and 1980 studies. Comparisons of habitats in terms of larval fish abundance and composition will be presented within this phenological context.

Results

66. Larval fish generally first appear in the lower Mississippi River in mid-April. Sampling on 23 and 24 March and 7 April 1978 over a variety of habitats did not result in the collection of any larval fish (Schramm and Pennington 1981). Similarly, no fish were collected during sampling in mid-March and early April of 1980. However, sampling on

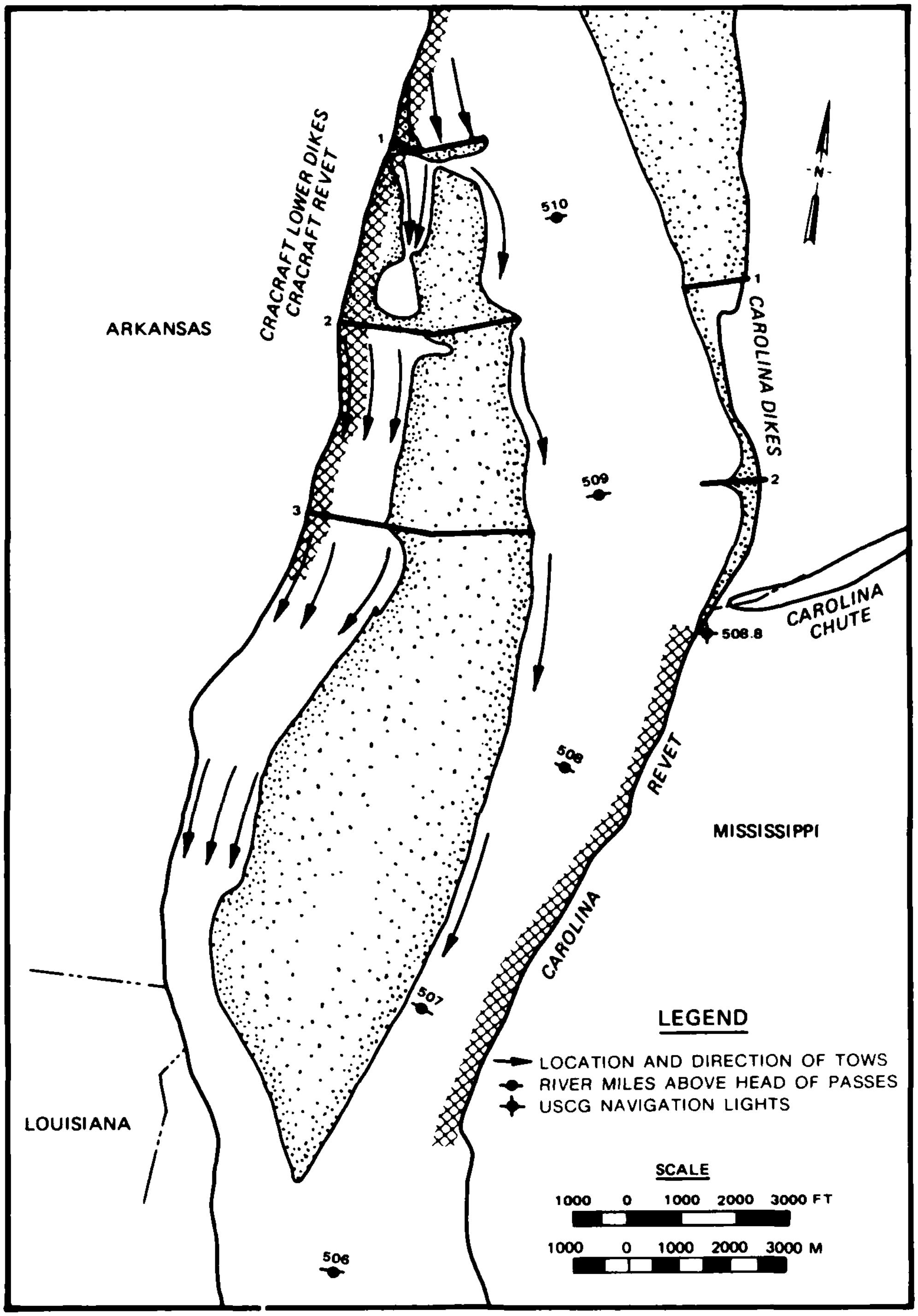


Figure 14. Map of Lower Cracraft Dike Field showing location and direction of tows during intensive dike field sampling

19 and 20 April 1978 and on 17 April 1980 resulted in diverse collections of larval fishes (Schramm and Pennington 1981; see also Figure 15). In both years the most common taxa in the earliest ichthyoplankton collections were shad (Clupeidae), common carp (*Cyprinus carpio*), buffaloes (*Ictiobus* spp.), temperate basses (*Morone* spp.), and crappies (*Pomoxis* spp.) (Figure 15). These fishes are all early spawners with peak ichthyoplankton abundances in the spring (Table 8). An interesting feature of the 17 April 1980 collection was the relatively uniform distribution of larval fishes among the various habitats (Figure 15 - see especially distribution in Matthews Bend). On 1 May 1980 common carp, buffaloes, and temperate basses were no longer collected in the abandoned channel (Matthews Bend), although these fishes were fairly common in the other sampled habitats (Figure 16). From early May on throughout the spring, summer, and early autumn, ichthyoplankton in the abandoned channel consisted almost exclusively of clupeids, *Lepomis* spp., and occasionally silversides (either the inland silverside, *Menidia beryllina*, or the brook silverside, *Labidesthes sicculus*). The relatively uniform ichthyoplankton distribution in mid-April 1980 may have been due to the rapidly rising river stage which culminated in the year's highest river stage in mid-April, the time of sample collection (Figure 2). At such times the Mississippi River extends from levee to levee and the sharp contrast in physical conditions which exists among habitats at lower flows is blurred by the massive, quickly moving river. The homogeneity of the river at this time, and its capacity to move and suspend objects (including larval fishes), may erase differences in ichthyoplankton composition which occur at lower flows.

67. Larval fish collections in May from the backwater habitats of Matthews Bend (sampled in 1978 and 1980) and Lake Lee (an oxbow lake connected by a chute to the river, sampled in 1979) showed that larval fish composition in the backwater habitats was markedly different from that of all the other habitats at this time (this dissimilarity between the backwaters and all other habitats was apparent for not only May but also throughout the remainder of the sampling period). Larval fishes

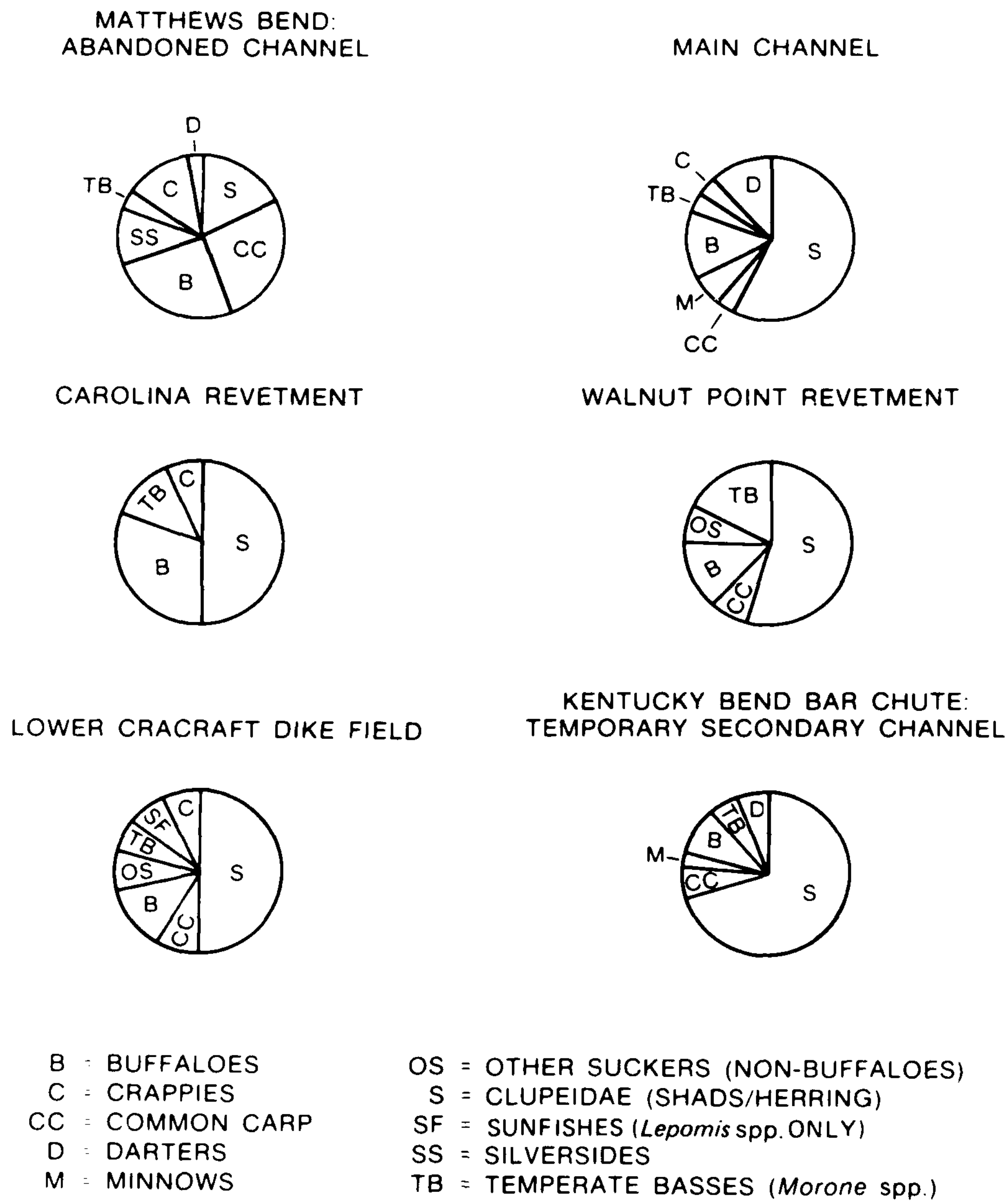


Figure 15. Larval fish composition in lower Mississippi River habitats on 17 April 1980 during flood conditions. Proportional abundances of the larval fish groups are equivalent to the area they encompass within the circles

Table 8

Overall Relative Abundance and Occurrence of Larval Fish Collected During Habitat Comparison Sampling in the Lower Mississippi River, 17 April Through 16 October 1980

Taxa	Total Specimens	Percent of All Larvae	Yearly Occurrence*	Abundance Peaks(s)*
Shads/herring	5,461	54.45	m-Apr to e-Oct	m and ℓ May
Sunfishes (*Lepomis* spp.)	2,202	21.96	m-Apr to e-Oct	ℓ-Jul and ℓ-Aug
Drum	1,549	15.45	e-May to e-Oct	e-Jun to e-Jul
Carpsuckers	332	3.30	m-May to m-Sep	ℓ-Jun
Minnows	135	1.34	m-Apr to m-Sep	Jul
Buffaloes	94	0.94	m-Apr to m-Jun	m-Apr to m-May
Grass carp	60	0.59	m-May to m-Sep	ℓ-Jun
Temperate basses	48	0.48	m-Apr to e-Aug	e-May
Common carp	46	0.46	m-Apr to m-Jun	m-Apr to e-May
Crappies	42	0.42	m-Apr to m-Jun	e and m-May
Silversides	19	0.19	m-Apr to ℓ-Aug	m-Apr and ℓ-Aug
Sauger	9	0.10	e-May to m-May	e-May
Darters	8	0.08	m-Apr to e-May	m-Apr
Goldeye	7	0.06	m-May to ℓ-May	m-May
"Other" suckers	4	0.05		
Damaged fish	13	0.13		
	10,029	100.00		

* The symbols e, m, and ℓ denote early, mid, and late portions of the various months, respectively.

in these backwaters in May were almost exclusively clupeids (Figure 16), with the inland silverside occasionally represented. These clupeids were present in very high densities in the abandoned channel in mid and late May 1980 (Table 9, Figure 16). The other habitats (revetted and natural banks, main channel, temporary secondary channel, and dike fields) also had clupeids as their dominant taxon in May, but also supported populations of larval carp, buffaloes, crappies, temperate basses, saugers (*Stizostedion canadense*), mooneyes (*Hiodon tergisus*), and goldeyes (*H. alosoides*) (Figures 16-19). These habitats (revetted and natural banks, main channel and temporary secondary channel, and the dike fields) were quite similar to each other in terms of ichthyoplankton composition in May.

68. Clupeids continued to be a dominant taxon in almost all lower Mississippi River habitats from the end of May through mid-June. Clupeid densities were generally high across all habitats from mid-May through mid-June with peak abundances in late May (Figures 16-19, Tables 8 and 9). Although skipjack herring (*Alosa chrysochloris*) and threadfin shad (*Dorosoma petenense*) may contribute to these high densities, gizzard shad (*D. cepedianum*) undoubtedly make up the overwhelming majority of larval clupeids at this time of the year. Gizzard shad are extremely numerous in the lower Mississippi River (Pennington, Baker, and Bond 1983) and spawn prolifically (Smith 1979) from early April through May (Pflieger 1975). In the backwaters, clupeids continued to be the dominant taxon through June. However, late June showed the beginning of a shift in dominance in the backwaters as *Lepomis* spp. began to appear in appreciable numbers and larval shad densities decreased (Figure 16).

69. June was also a pivotal month for ichthyoplankton composition in the main-stem sampling locations (revetted and natural banks, main channel and secondary channels, and the dike fields) as the early spawners ceased reproducing. In both the 1978 and the 1980 studies no larval saugers were collected past the end of May; larval goldeyes, mooneyes, carp, and crappies were not collected past mid-June, and larval buffaloes were no longer present past late June (Table 8). While

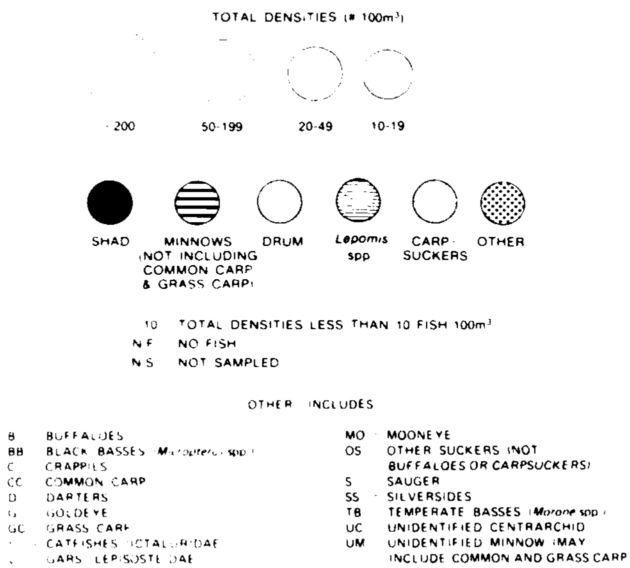


Figure 16. Larval fish composition and densities by dates in an abandoned channel, an oxbow lake, and the main channel. Proportional abundances of the larval fish groups are equivalent to the area they encompass within the circle (Continued)

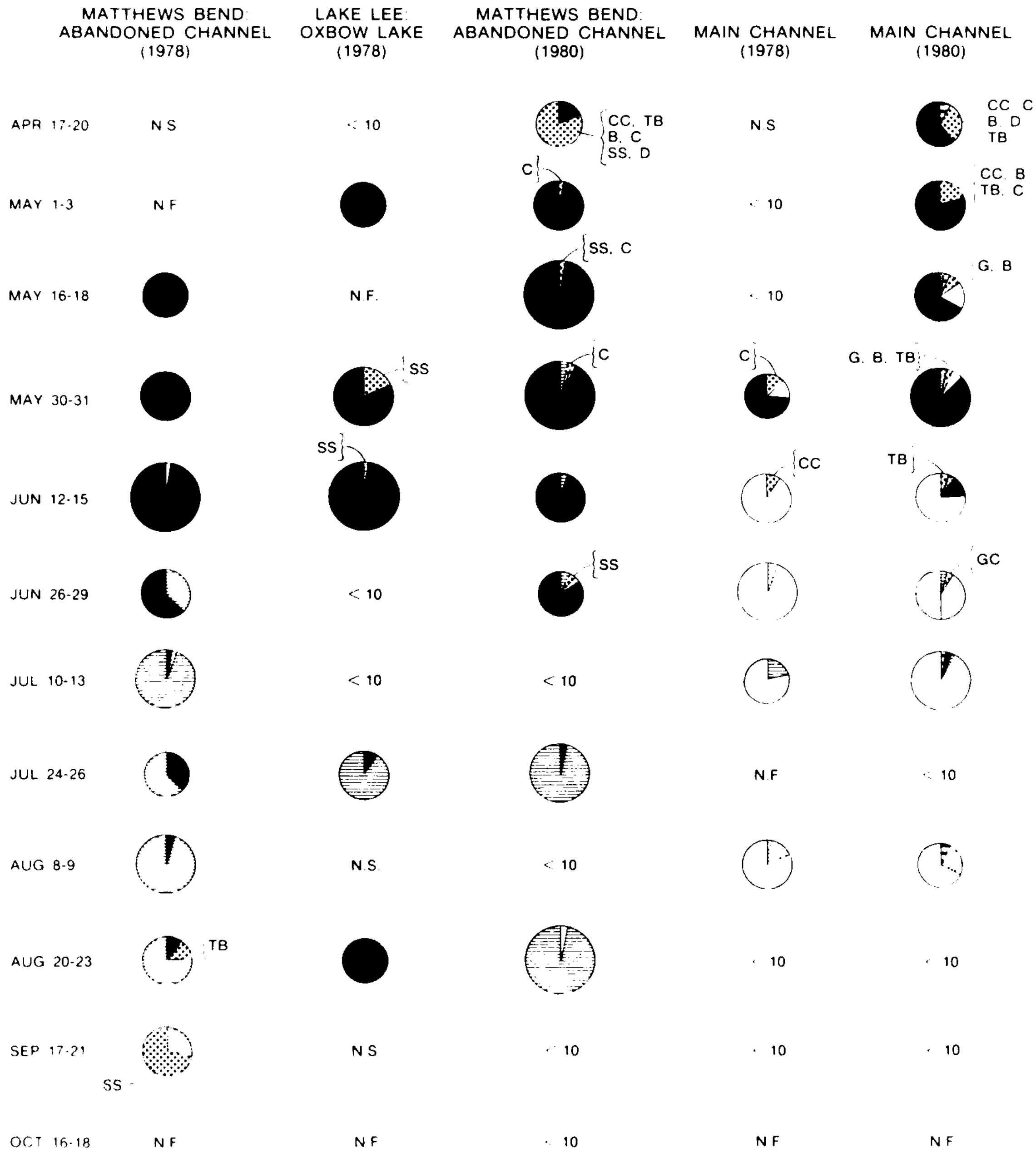


Figure 16. (Concluded)

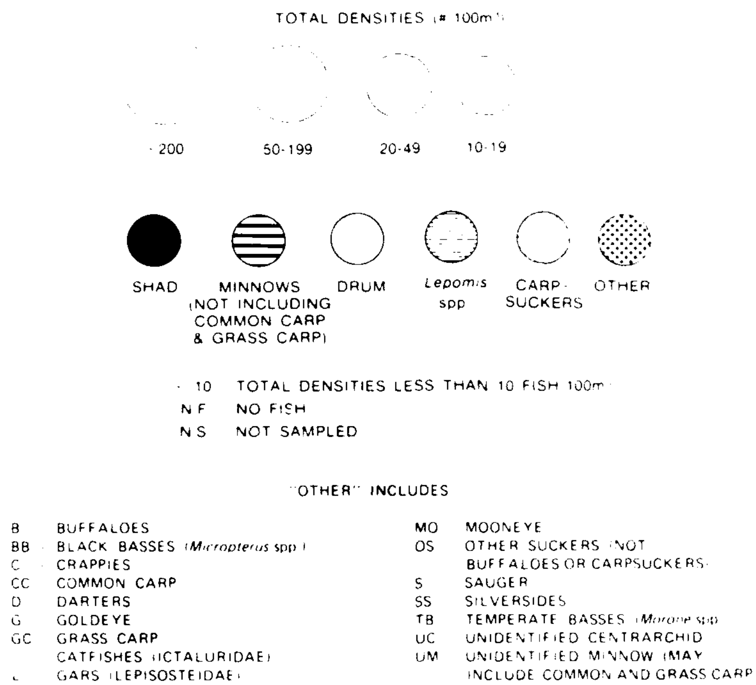
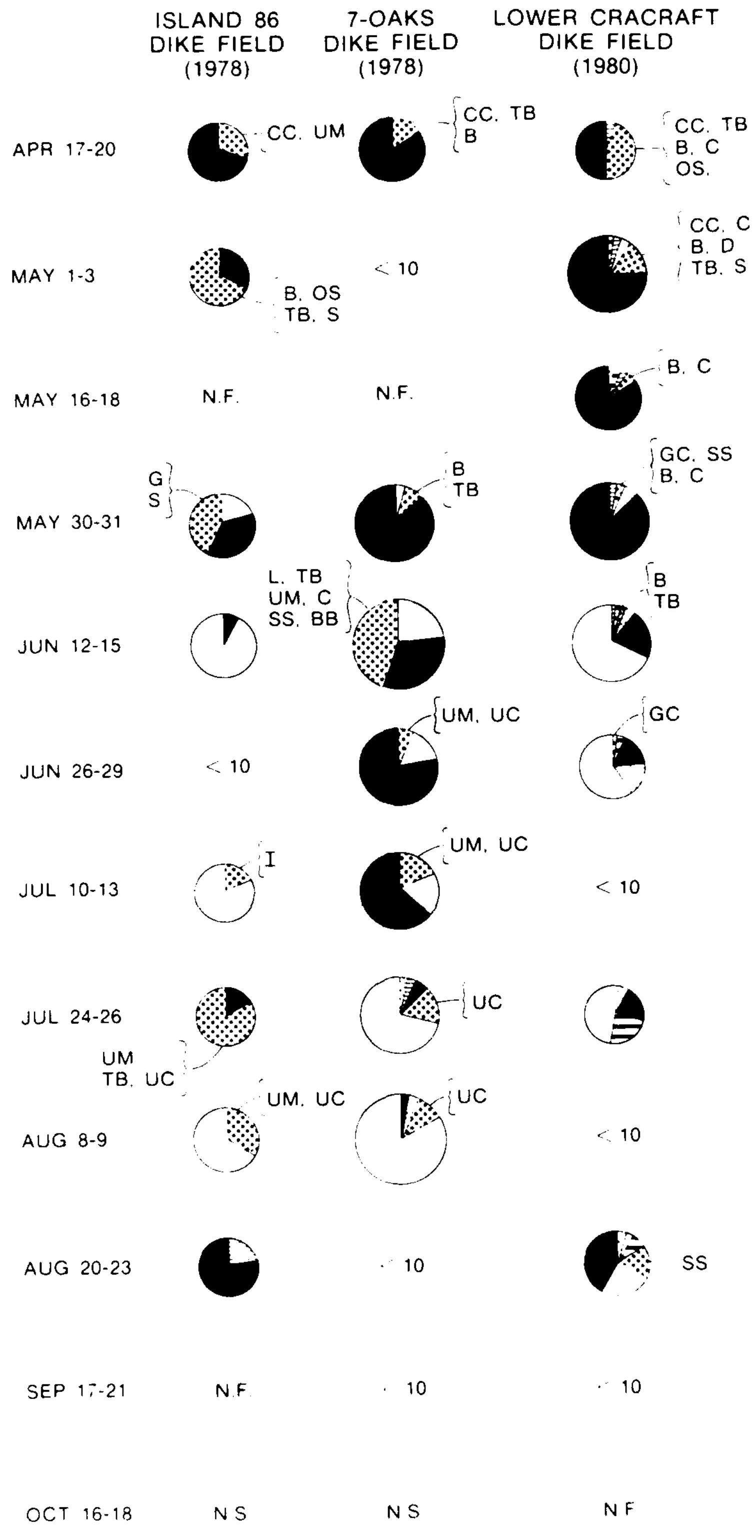


Figure 17. Larval fish composition and densities by dates in three dike fields. Proportional abundances of the larval fish groups are equivalent to the area they encompass within the circle (Continued)



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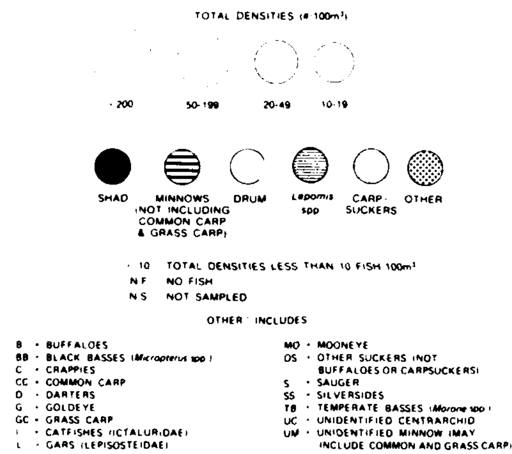

Figure 18. Larval fish composition and densities by dates along two natural banks, in a permanent secondary channel, and in a temporary secondary channel. Proportional abundances of the larval fish groups are equivalent to the area they encompass within the circle (Continued)

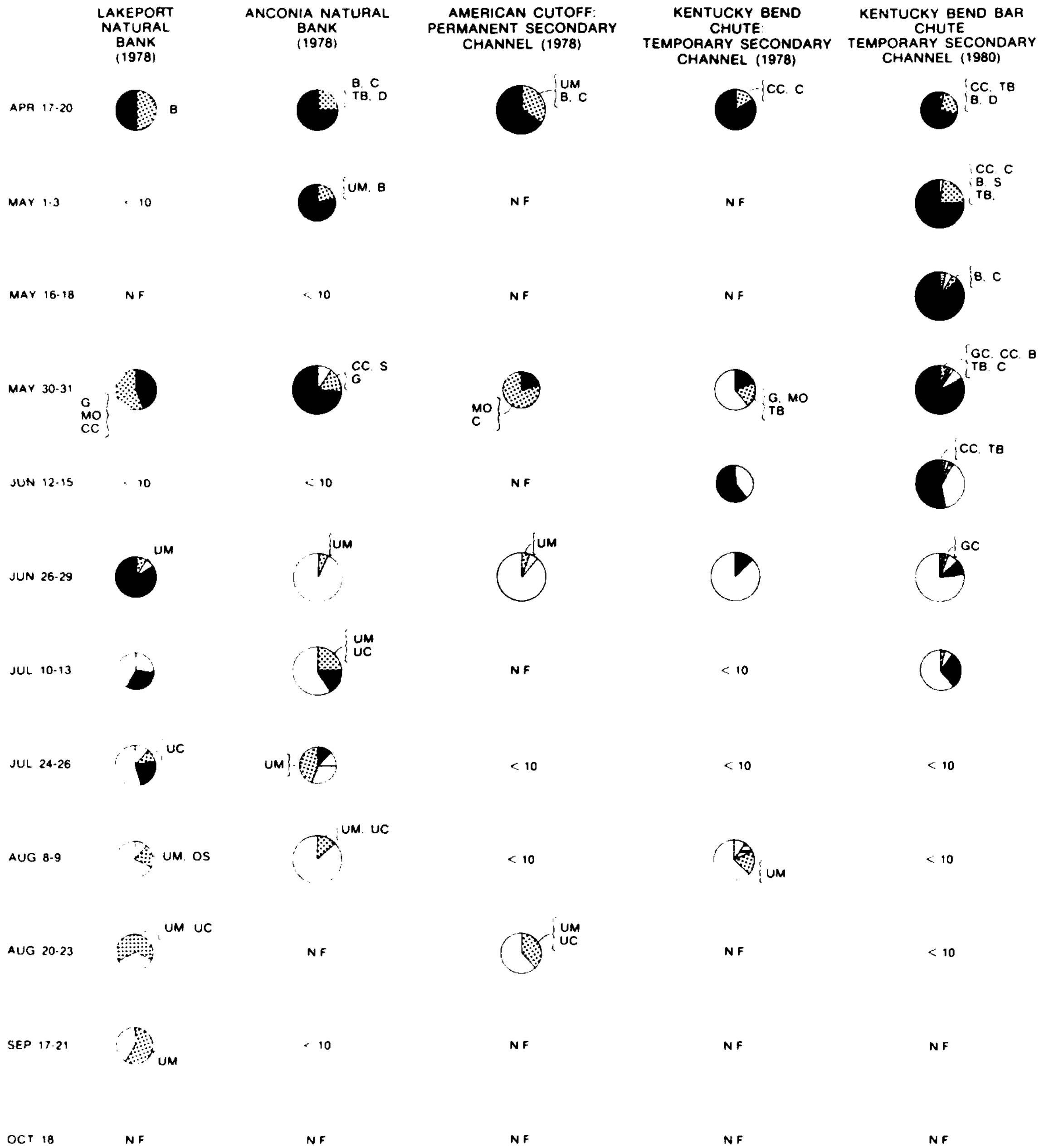

Figure 18. (Concluded)

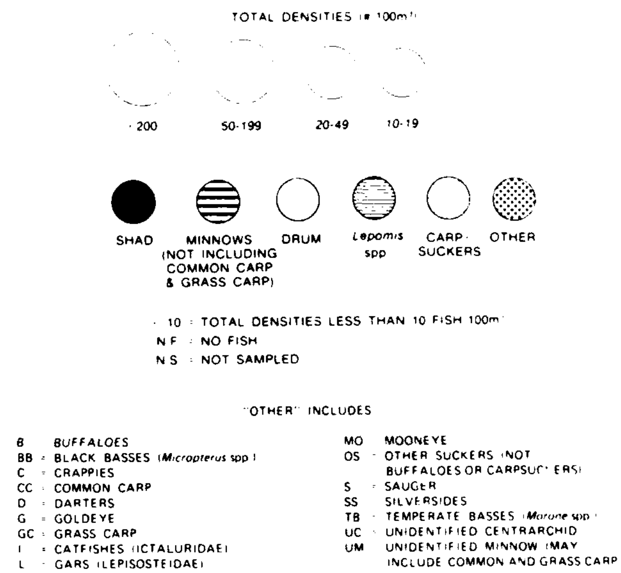

Figure 19. Larval fish composition and densities by dates along three revetted banks. Proportional abundances of the larval fish groups are equivalent to the area they encompass within the circle (Continued)

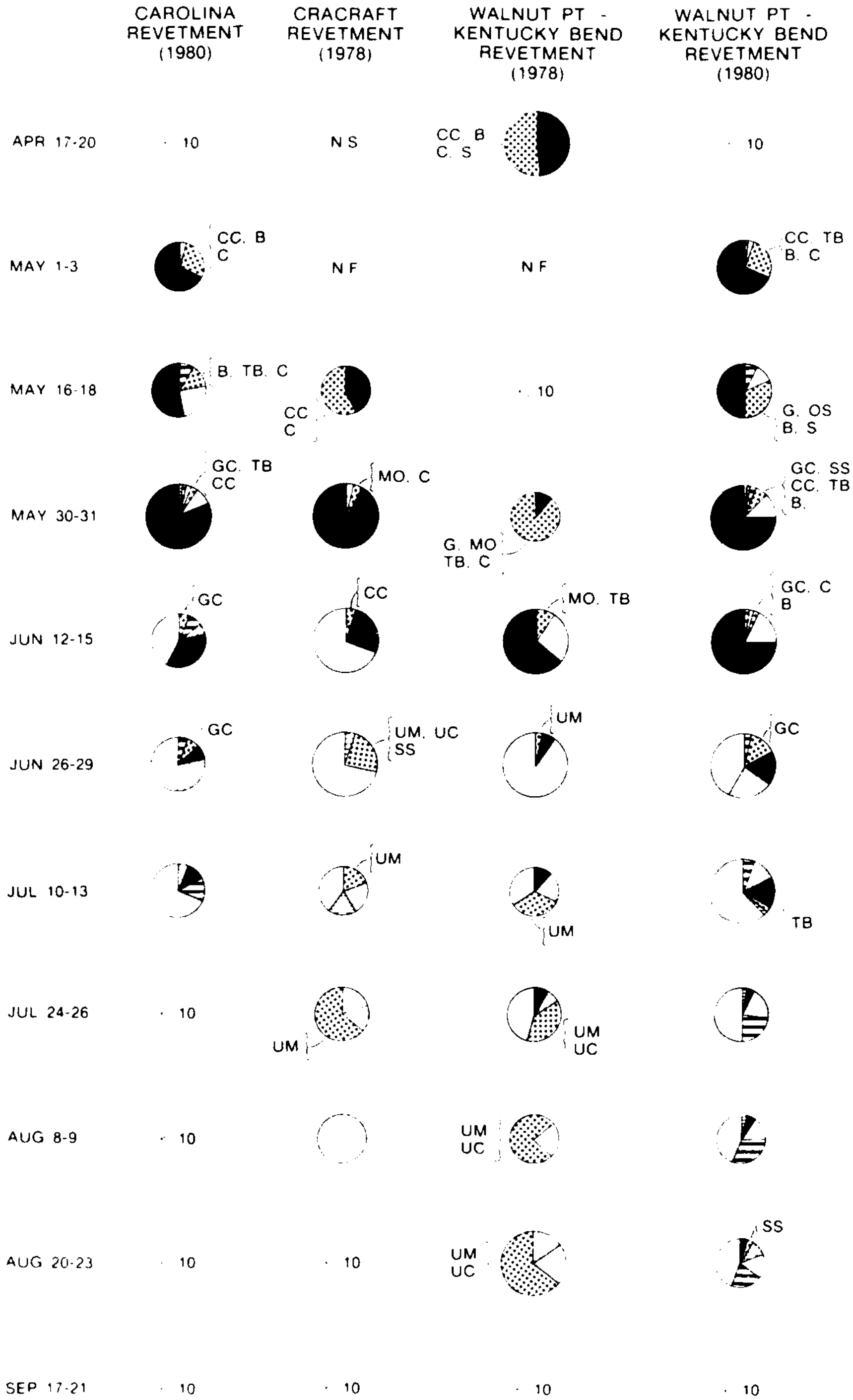

Figure 19. (Concluded)

Table 9

Comparative Abundance (No./100 m^3) of Larval Fish in Seven Lower Mississippi River Habitats Sampled in 1980

Date	Main Channel	Carolina Revetment	Walnut Point Revetment	Lower Cracraft Dike Field	Leota Dike Field	Kentucky Bend Bar Chute	Matthews Bend
17 April	17.8	9.5	7.2	12.9	5.5	24.0	22.0
1 May	26.7	18.5	34.1	86.8	33.8	78.0	41.5
16 May	36.5	32.8	23.8	37.1	25.1	106.1	976.0
30 May	196.3	75.7	100.6	133.0	75.2	178.6	606.8
12 June	25.4	24.1	176.3	97.1	77.2	126.3	25.5
26 June	21.2	47.5	103.6	48.2	45.5	99.5	17.7
10 July	78.8	19.6	107.6	6.2	26.7	43.4	1.4
24 July	5.9	5.9	28.4	11.1	NE	8.4	98.7
8 August	11.7	8.9	16.5	3.7	NE	1.0	2.3
20 August	7.6	3.8	12.0	19.5	NE	3.2	777.8
4 September	4.2	4.8	5.4	2.5	7.3*	6.0	32.2
17 September	4.8	2.9	5.4	5.6	NE	1.0	5.5
2 October	0.6	--	0.5	--	NE	--	1.1
16 October	--	--	--	--	NE	--	--
Mean No./100 m^3	31.2	18.1	44.4	33.1	37.0	48.2	186.3
Total Effort (m^3)	2631	2260	2433	2551	1131	2300	2702

* Sample taken on 10 September.
NE = no effort, i.e. not sampled.
-- = no larval fish collected in samples.

recruitment of larval saugers, goldeyes, mooneyes, carp, crappies, and buffaloes ceased at various times during June, freshwater drum (*Aplodinotus grunniens*) and carpsuckers (*Carpiodes* spp., mostly river carpsuckers - *Carpiodes carpio*) became the dominant larval fishes in the main-stem habitats during mid to late June. Both the drum and carpsuckers are present in the ichthyoplankton community over extended periods (drum were present from 1 May through September in 1980; carpsuckers were present from mid May to late August in 1980). However, peak abundance of drum occurred from early June to early July and peak abundance of carpsuckers occurred in late June (Table 8).

70. The backwater habitats continued to have a very dissimilar ichthyoplankton composition from that of the main-stem locations for the remainder of the sampling period. *Lepomis* spp. was generally the dominant taxon in the abandoned channel from July through September in both 1978 and 1980, with clupeids and occasionally the inland silverside present in lesser numbers (Figure 16). Larval *Lepomis* spp. (mostly bluegill, *Lepomis macrochirus*) were occasionally quite abundant in the abandoned channel with 777 individuals/100 m^3 of water on 20 August 1980 (Table 9, see also Figure 16). The other backwater habitat investigated, the oxbow lake (Lake Lee), had *Lepomis* spp. as a dominant taxon on 25 July 1978 while the ichthyoplankton collected on 22 August 1978 consisted solely of clupeids (Figure 16). While the larval clupeids present in the backwaters in the spring were largely gizzard shad, it is likely that the larval shad in such habitats in mid to late summer were threadfin shad. Gizzard shad are spring spawners; threadfin shad also spawn in the spring but individuals who have hatched early in the year commonly mature and then spawn late in their first summer of life (Pflieger 1975).

71. While larval lepomids and shad dominated the ichthyoplankton in the backwaters, freshwater drum and carpsuckers continued as the dominant larval fishes in the main channel from mid-June throughout the remainder of the sampling year (Figure 16). The spawning habits of the freshwater drum are largely responsible for the abundance of drum larvae in the main channel. Drum spawn in open water and the eggs float until

hatching (Davis 1959). Other main-stem habitats such as the permanent and temporary secondary channels, revetted and natural banks, and the dike fields showed larval fish compositions in late June, in July, and in August which were generally similar to that of the main channel's, i.e. drum and carpsuckers were usually among the dominant larval fishes in all these main-stem locations (Figures 17-19). However, the temporary secondary channel, the bank habitats, and the dike fields consistently showed some dissimilarity from the main channel ichthyoplankton composition, especially in the relative abundance of clupeids present (relative clupeid abundances were quite low in the main channel in comparison to these other habitats - Figure 16). Fortunately, the 1980 intensive study of ichthyoplankton distribution in Lower Cracraft Dike Field showed the cause of this dissimilarity in dike field vs. main channel composition.

72. The year 1980 was fairly typical in terms of river stage, with high flows in spring and falling river levels into the summer (Figure 2). July and August were periods of relatively low water, and, as such, the dike field pools became slack-water areas. A primary objective of the intensive sampling in Lower Cracraft Dike Field consisted of comparing results from ichthyoplankton tows taken within the pools (inside of the middle bars) to those collected on the river-side of the middle bars (Figure 14). This sampling showed that very marked differences exist between these neighboring areas, both in ichthyoplankton composition and in density (Figures 20-23). Ichthyoplankton composition on the river-side of the middle bar was consistently composed of drum and carpsuckers, i.e. similar to the larval fish composition of the main channel. In contrast, the dike field pool areas were consistently dominated by dense populations of shad, *Lepomis* spp., and inland silverside, i.e., similar to the fish composition of backwater habitats such as the abandoned channel (Figures 16, 20-23). The causation of the compositional pattern shown by the dike fields for the habitat comparison study (e.g. Lower Cracraft in 1980 on 24 July vs. 20 August - Figure 17) was therefore made evident. For the habitat comparisons study (Figure 17) Lower Cracraft Dike Field was sampled at two points: upstream

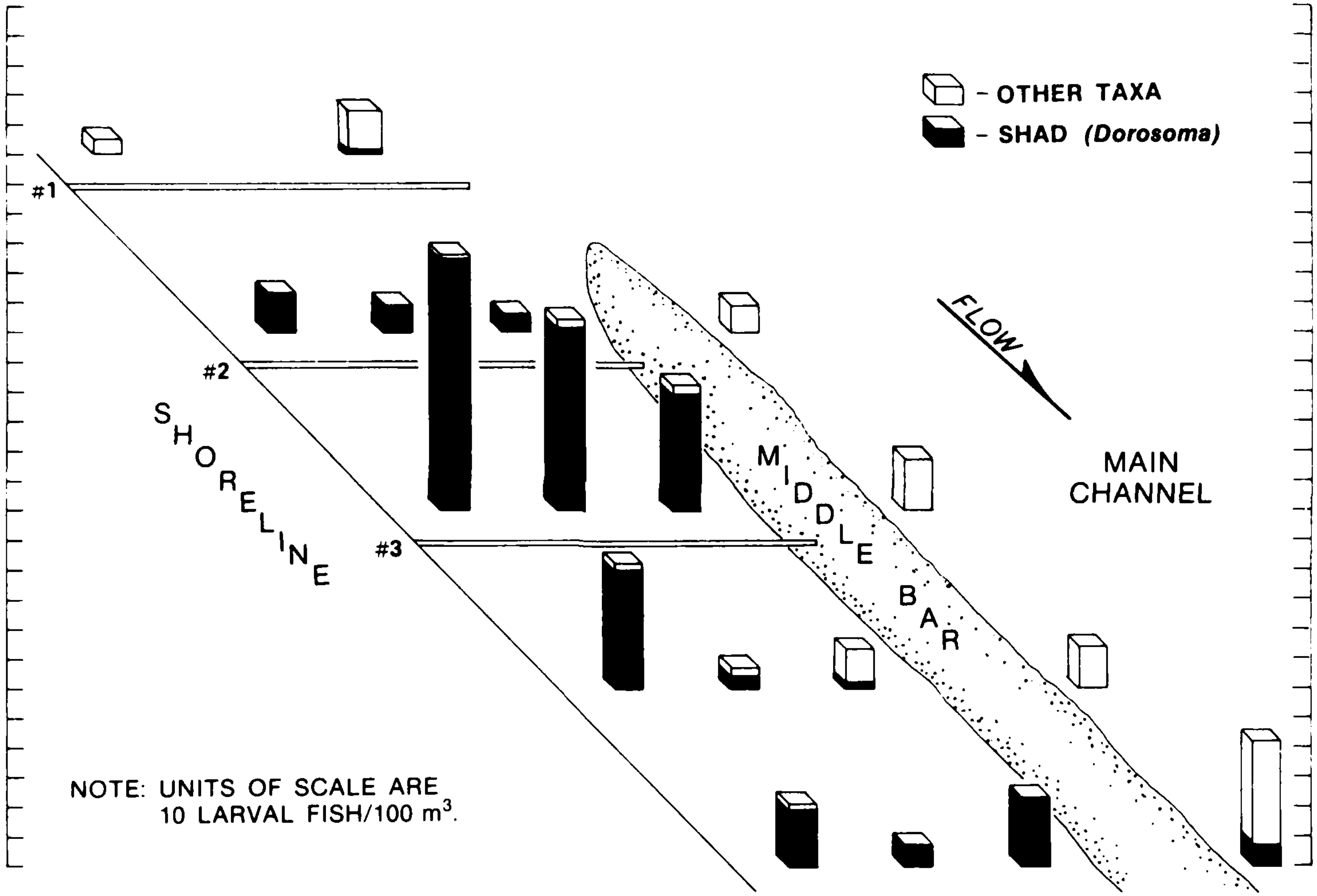

Figure 20. Catch per unit of effort (No./100 m^3) of larval fish in the Lower Cracraft Dike Field, lower Mississippi River, on 10 July 1980

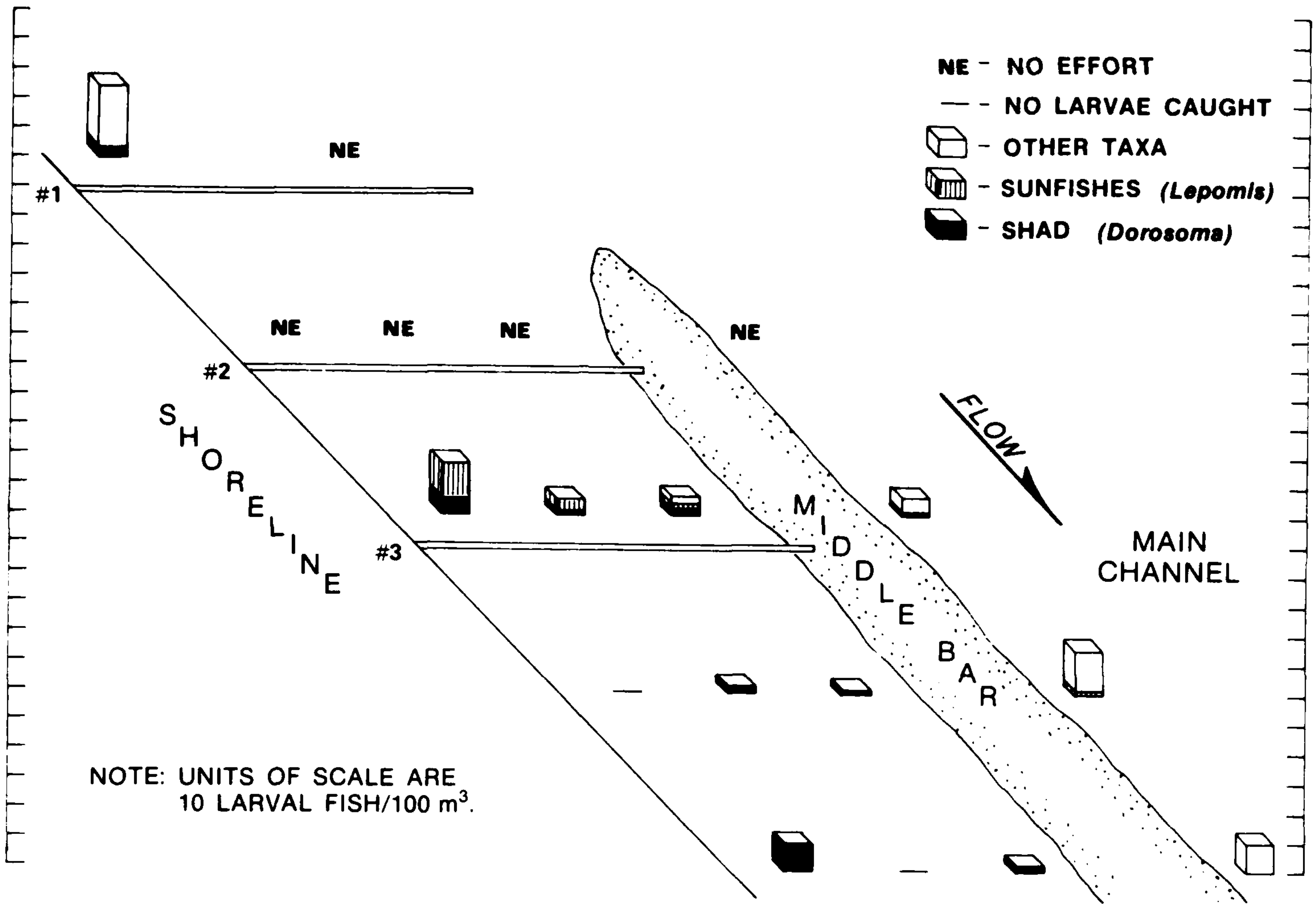

Figure 21. Catch per unit of effort (No./100 m^3) of larval fish in the Lower Cracraft Dike Field, lower Mississippi River, on 24 July 1980

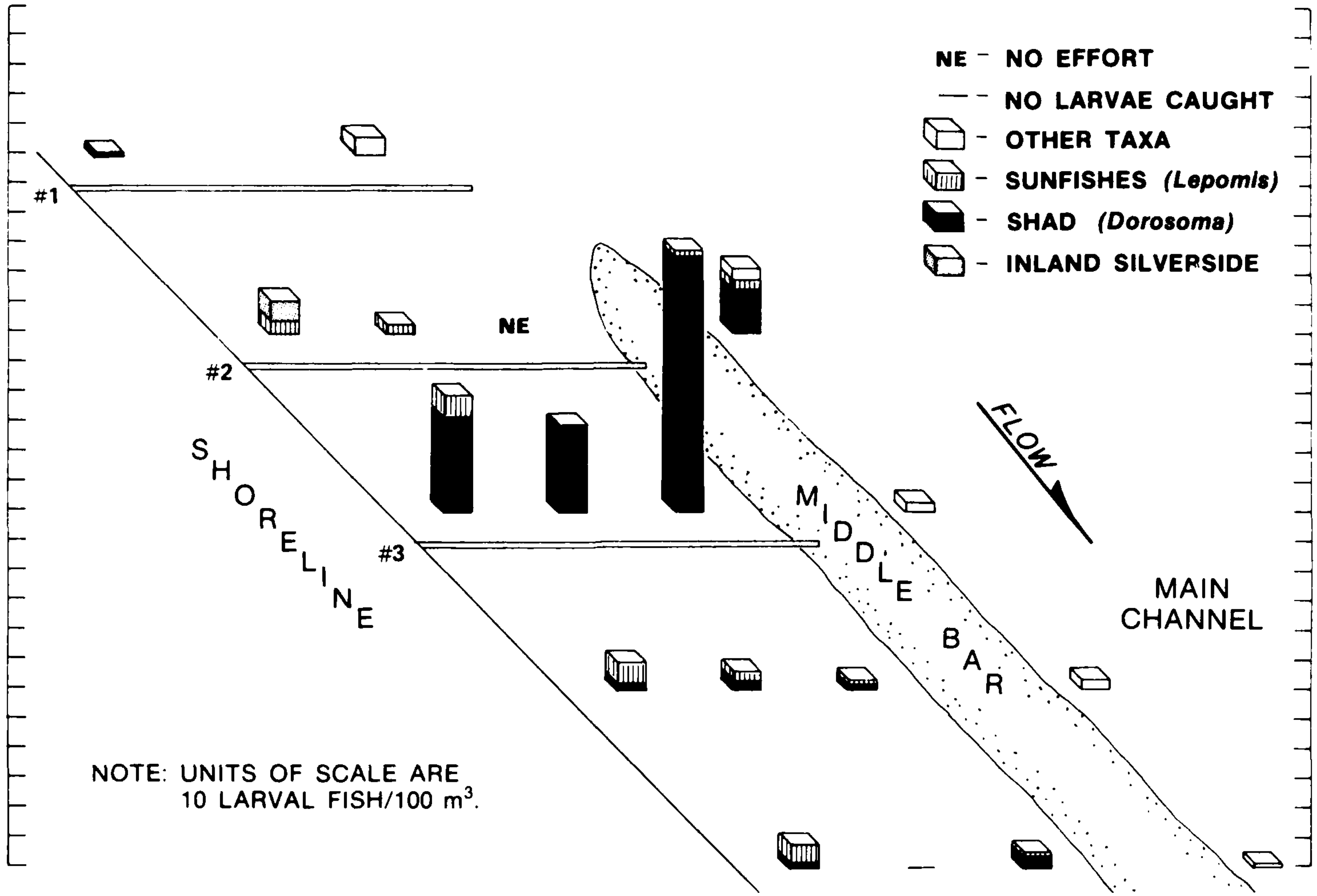

Figure 22. Catch per unit of effort (No./100 m^3) of larval fish in the Lower Cracraft Dike Field, lower Mississippi River, on 8 August 1980

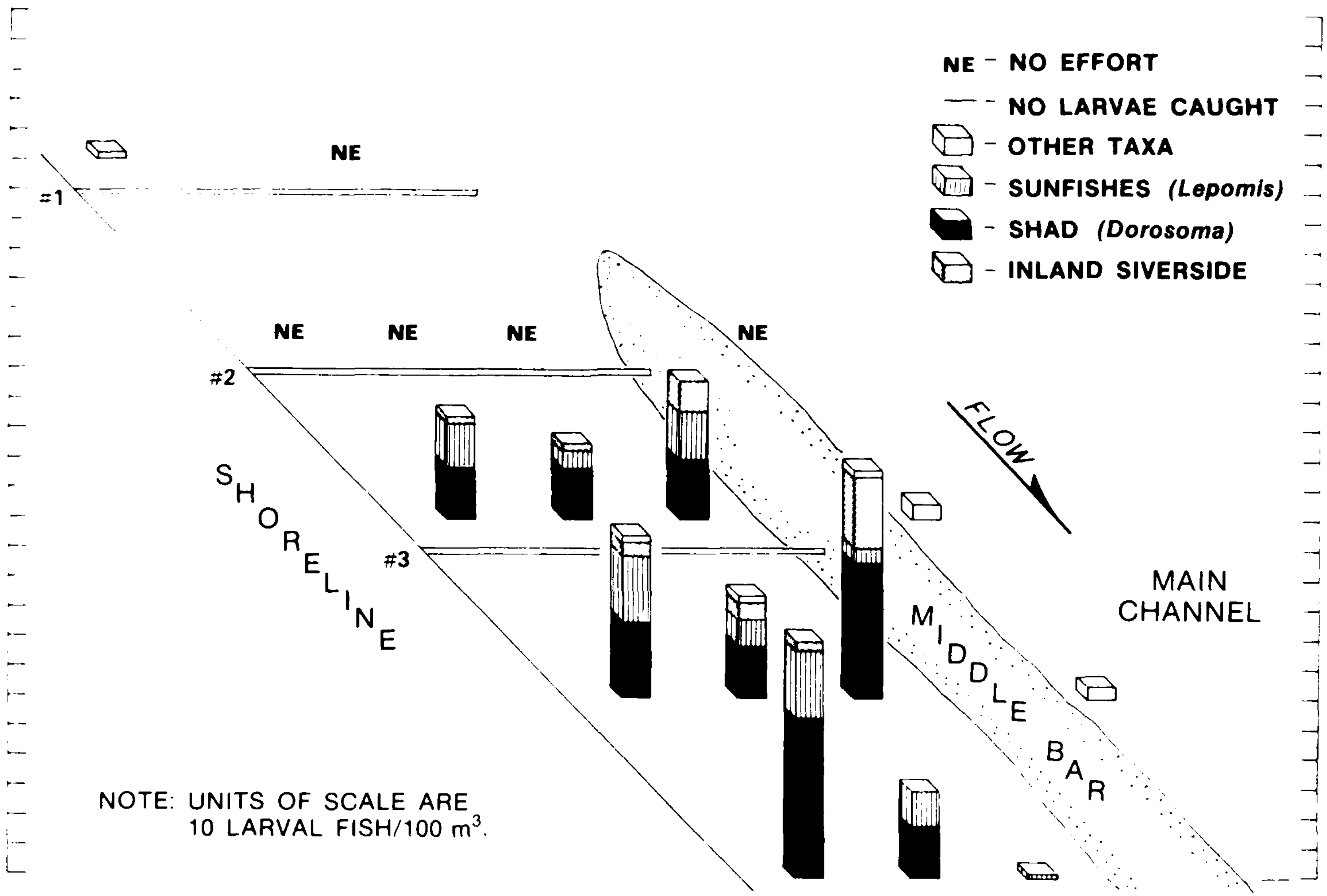

Figure 23. Catch per unit of effort (No./100 m^3) of larval fish in the Lower Cracraft Dike Field, lower Mississippi River, on 20 August 1980

of the first dike and from a station in the pool area below the third dike. The intensive study of Lower Cracraft (Figures 20-23) showed that the larval fish collected above the first dike were those associated with the moving river (drum and carpsuckers) while the larval fishes in the pool area below the third dike were those associated with slack-water areas (shad, *Lepomis* spp., and silversides). The 24 July and 20 August (1980) Lower Cracraft ichthyoplankton compositions, as determined for the habitat comparison study (Figure 17), are therefore composites from the two sampling points; the drum predominate in the 24 July samples (Figure 17) because of the relatively high abundance of drum above dike 1 on that date (Figure 21); on 20 August high densities of shad, *Lepomis* spp., and inland silverside below dike 3 "overwhelm" the carpsucker numbers above dike 1 (Figure 23) and hence the resultant composite (Figure 17).

73. The 1978 diel study (Schramm and Pennington 1981) showed that maximum ichthyoplankton diversity along a revetted bank occurs at dusk, with relatively high diversity at night and dawn, and low diversity in the daytime. Significant differences in densities also occurred over the 24-hr cycle with lowest total densities at midday, an increase during the afternoon to a maximum at dusk, followed by a decrease during the night to a low density at dawn. Increased nocturnal ichthyoplankton abundances have also been reported from the Susquehanna River (Gale and Mohr 1979), the Missouri River (Hergenrader et al. 1982), and the lower Mississippi River (Gallagher and Conner 1980). Although daytime net avoidance might be invoked as an explanation for the increase in numbers collected at night, this is probably an unlikely explanation in the highly turbid and turbulent Mississippi River. A more likely explanation would be a behavioral response of the larval fishes (e.g. increased movement) triggered by darkness.

Discussion and Ecological Implications

74. Three principal factors determine ichthyoplankton composition and distribution in the lower Mississippi River: (a) larval phenology,

(b) habitat characteristics, and (c) river stage. Phenological distribution underlies all other distributions since both the 1978 and the 1980 study show a marked succession of ichthyoplankton species throughout the reproductive period. The progeny of early spawners such as gizzard shad, mooneyes, goldeyes, carp, buffaloes, and saugers dominate spring and early summer ichthyoplankton collections. However, no larval saugers, goldeyes, mooneyes, carp, crappies, or buffaloes were ever collected past late June in either 1978 or 1980. Instead, progeny of late spawners such as freshwater drum, carpsuckers, and *Lepomis* spp. dominate the mid to late summer ichthyoplankton community. Hergenrader et al. (1982) observed a similar pattern in the Missouri River, with sauger and buffaloes among the dominant larval fishes in May, and drum and carpsuckers dominant from June through July.

75. The distribution of larval fishes, summarized in Figure 24, is closely tied to existing physical conditions in the various habitats, as evidenced in mid to late summer by the markedly dissimilar ichthyoplankton compositions in the backwaters (shad, *Lepomis* spp., and silversides) vs. that of the main channel (drum and carpsuckers) (Figure 14). The intensive study at Lower Cracraft Dike Field confirmed this distributional pattern. The slack-water pools formed in the dike fields on the inside of the middle bars were populated by larval fishes typical of backwater habitats, while the ichthyoplankton community on just the other side of the middle bar (the river side) was quite similar to that of the main channel habitat (Figures 20-23). This dichotomy in ichthyoplankton composition was evident throughout almost the entire reproductive period with the ichthyoplankton of backwater habitats markedly dissimilar from main-stem communities (main channel, permanent and temporary secondary channels, and natural and revetted banks). The less pronounced but distinct compositional dissimilarities between the main channel (and permanent secondary channel) vs. the bank and temporary secondary channel habitats were most pronounced at low flows. At low river stages, flow from upstream ceases in the temporary secondary channel, and numerous eddies and small slack-water areas form along the bank habitats. The occurrence of larval fishes such as clupeids in these

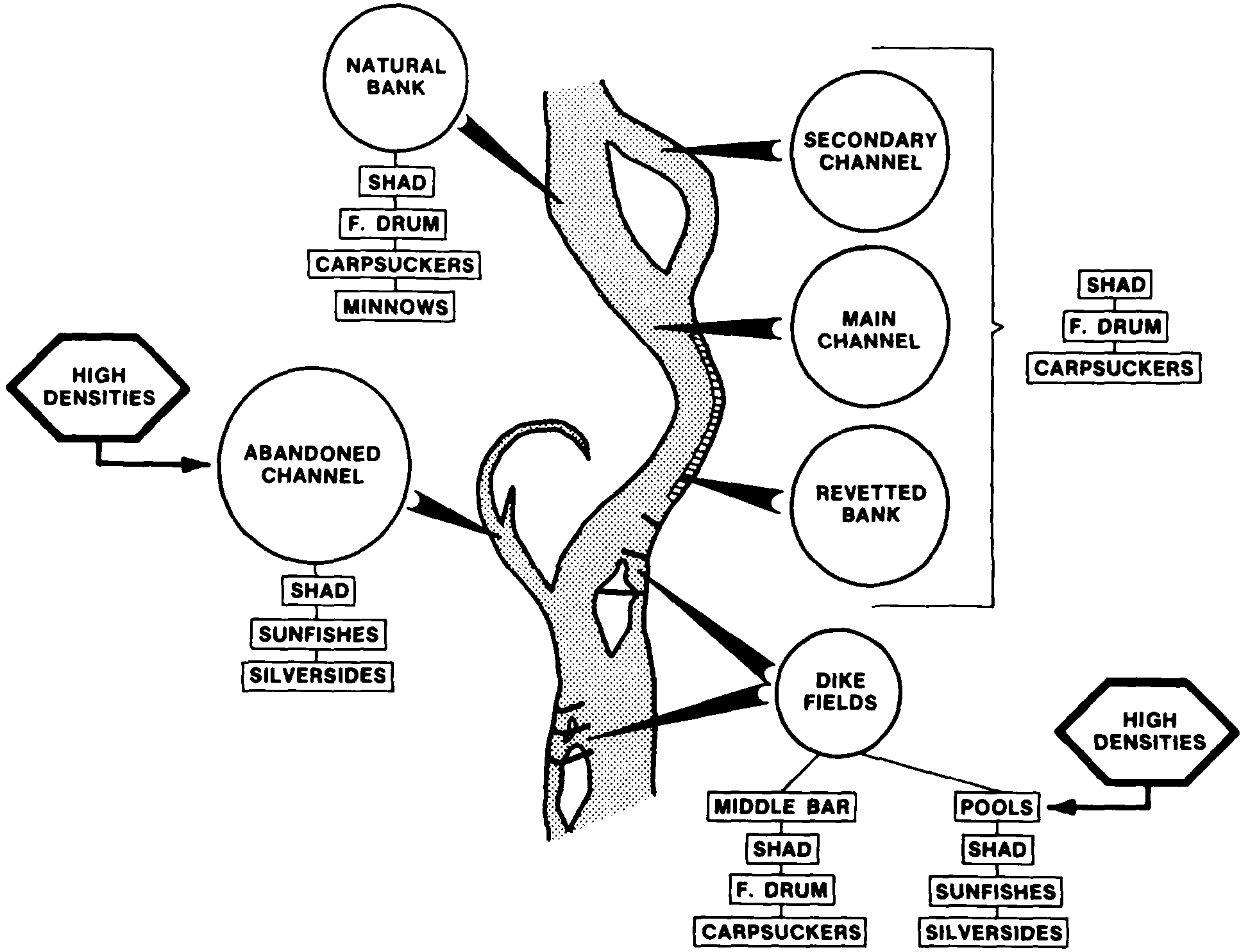

Figure 24. Schematic drawing of lower Mississippi River ichthyoplankton composition showing the larval fishes most commonly collected in the investigated habitats. Dike field middle bar refers to the aquatic areas on the main channel side of the middle bars

habitats could result from the spawning of adults in these small areas and/or perhaps because of a behavioral preference of some larval fishes for these areas. Such habitats would then possess a "mixture" of larval fishes with a contribution from larval fish common in the downstream-moving water column (drum and carpsuckers) and those usually found in backwater situations.

76. The mid to late summer main channel-backwater dichotomy in ichthyoplankton composition is not confined to the lower Mississippi River. A Missouri River comparison of ichthyoplankton composition in the main channel vs. that of the backwaters (Hergenrader et al. 1982) showed that drum made up 83.1 percent of the larval fish collected in the main channel, while gizzard shad constituted only 2.9 percent. In the backwaters (sloughs, tributary streams, and chutes), however, a converse situation existed, with gizzard shad constituting 66.5 percent of the larval fish collected and drum constituting only 11.6 percent. In addition, 98 percent of the centrarchid larvae collected from the Missouri (over both the main channel and the backwater samplings) were taken in the backwater areas. Similarly, in the Ohio River, Moller, Stewart, and Miller (1980) and Miller, Moller, and Meininger (1981) found drum to be a dominant larval fish in the main-stem river; larval drum were virtually absent from river backwaters. Clupeid larvae, on the other hand, were found in the backwaters at densities of 10 to 100 times that of the clupeid numbers in the river main-stem. In these Ohio River studies peak centrarchid numbers were also found in the backwater tributaries.

77. The differences in ichthyoplankton composition between the main channel and backwaters are due mainly to the spawning preferences of the adult fishes and the properties of the eggs produced. Freshwater drum spawn in the open water (Davis 1959, Becker 1983), producing eggs which float until hatching (Davis 1959). Gizzard shad spawn in slackwater areas, producing adhesive eggs which sink to the bottom and attach to the first object they contact (Pflieger 1975).

78. Although backwaters are the preferred spawning area for clupeids, and highest clupeid densities are recorded from the backwater

areas (Figure 16 and Table 9), larval shad are fairly common in all habitats in the spring (Figures 15-19). This may result because: (a) although shad prefer to spawn in backwaters, some of the clupeids may spawn somewhat more randomly, and/or (b) larval clupeids in the main-stem may be due to washout. Moller, Stewart, and Miller (1980) have postulated that larval clupeids in the main-stem Ohio River have resulted from washout from the tributaries. It seems fairly certain that in the lower Mississippi River the high river stage usually coincident with the initial appearance of larval fishes exerts a strong influence on ichthyoplankton distribution. The 17 April 1980 sampling, occurring at a peak in river stage, showed a homogeneity of ichthyoplankton distribution (Figure 15) which was evident only on this date. The larval fish composition in the abandoned channel provided the clearest example of this phenomenon; composition in the abandoned channel as of 17 April was quite diverse, and fairly similar to other habitats. However, all of the May samples (taken at periods of falling river stage) from the abandoned channel show a more typical backwater community (Figure 16).

79. While high flows at elevated river stages seem certain to have influenced ichthyoplankton distribution, river stage at low flows is also important in determining distribution in the dike fields and the bank habitats. The dike field pools have been shown to support high densities of larval fishes which are also found in the naturally occurring backwaters of the lower Mississippi River. The use of the dike field pools as "backwaters" is of course dependent on the occurrence of low river stages during the reproductive periods of these fishes. Normally fairly low river stages exist in July and August, and the dike fields become largely a series of slack-water pools. Atypical higher river stages which might occur at this time would markedly reduce the suitability of such areas as spawning sites for shad, *Lepomis* spp., and inland silverside. The lower river stages which normally occur in mid to late summer are also responsible for the creation of physical conditions in bank habitats (eddies, reduced current areas) which are somewhat different from the main channel's and result in some

differences in bank vs. main channel ichthyoplankton communities.

80. The 1978 and 1980 studies of larval fishes in the lower Mississippi River have shown backwaters to be very important because: (a) the ichthyoplankton community of the backwaters is of a distinctly different composition than that of the river proper; and (b) the highest densities of larval fishes in the river system occur in the backwaters. In addition, a number of large-river studies have shown backwaters to be very important nursery areas for juvenile fishes. Hergenrader et al. (1982) found that in their larval fish collections in the main-stem Missouri River only 0.11 percent of the fish were juveniles. However, in backwaters such as cut-off chutes and tributary streams juveniles made up 22.0 percent and 35.6 percent, respectively, of their collections. Shallow side channels with low flow have been shown to be important nursery areas in the upper Mississippi River (Ellis, Farabee, and Reynolds 1979). Likewise, Cavender and Carter (1982) indicated the importance of backwater areas as nursery grounds for young-of-the-year fish in the Ohio River.

81. Rivers such as the Ohio have large backwater areas which are created as tributary streams enter the river. For example, a 91-mile stretch of the Ohio River's Meldahl Pool has 75 tributaries entering into it (Moller, Stewart, and Miller 1980). At normal pool elevation the backwater portions of these tributaries total 2666 acres. Because of its topography the lower Mississippi River, by contrast, has a marked paucity of tributaries. For example, the 62-mile reach of the lower Mississippi River which was used for the EWQOS studies described in this report has no tributaries directly entering the river. The existing backwaters that are confluent with the lower Mississippi River are therefore ecologically very important. In addition to the preservation of such areas, it is important that they be kept physically open to the river so as to be accessible to the river's fishes which use them for spawning.

82. The dike fields, whose pools have been shown to be populated by high densities of larval fishes during low flows, are also of concern. Such areas, by their nature, accrete sand. The formation of the

middle bars is, of course, necessary to form the slack-water pools. Whether the lower Mississippi River's dike fields will continue to accrete sediment to a point that the dike fields' pools will fill in and become terrestrial habitat is unknown. If such "terrestrialization" occurs, engineering designs which could extend the aquatic life of the dike fields would be ecologically beneficial for the lower Mississippi River.

PART VI: FISHES

Introduction

83. The primary objective of the EWQOS investigations of fishes has been to describe the composition and abundance of fish communities in the lower Mississippi River. The distribution of fishes was investigated in two studies: a 1978 pilot study (Pennington et al. 1980), and an intensive study over 1979-1980 (Pennington, Baker, and Bond 1983). Along with characterizing fish distribution in the lower Mississippi River, the pilot study also evaluated a wide variety of sampling gears to determine gear effectiveness in different conditions. The pilot study was conducted from April through December 1978, between river miles 499 and 525. Habitats investigated included three abandoned channels, an oxbow lake, three natural (i.e. non-revetted) banks, five revetted banks, five dike fields, two sandbars, two secondary channels, an inundated floodplain area, and a borrow pit. A wide variety of gears was used and evaluated, including gill nets, trammel nets, hoop nets, minnow traps, slat traps, seines, electroshocking, and a trawl.

84. Eight sites were chosen for the intensive study, including three dike fields, two revetted banks, two natural banks, and an abandoned channel (Table 10). Comparisons could then be made between the natural and revetted bank habitats. The abandoned channel is of special interest since it is a backwater habitat rather than a main-stem area. The study area encompassed a 60-mile reach of the lower Mississippi River (river miles 506-566) and therefore included most of the pilot study area within its limits. Sampling gears included hoop nets, gill nets, minnow traps, seines, and electroshocking (Table 10). Standard units of fishing effort for each gear type and details concerning gear use are listed in Table 10. Fishes were collected over a high flow period (April 1979), two moderate flow periods (June and September 1979), and two low flow periods (November 1979 and September 1980).

85. Optimally, all gear types would be used in each of the study sites. Unfortunately, this is not possible in the lower Mississippi

Table 10

Fish Sampling Efforts* by Gear Type** Across Sampling Dates and Habitats,† 1979-1980

Habitat	Apr 79					Jun 79					Sep 79					Nov 79					Sep 80					Totals				
	ES	HN	EG	SN	MT	ES	HN	EG	SN	MT	ES	HN	EG	SN	MT	ES	HN	EG	SN	MT	ES	HN	EG	SN	MT	ES	HN	EG	SN	MT
DFC	11	18	--	--	--	10	62	--	7	16	17	68	--	11	12	22	56	12	8	14	23	--	17	12	--	83	204	29	38	42
DFL	10	19	--	--	--	11	62	--	8	19	16	66	--	17	22	13	36	6	10	17	10	--	12	18	--	60	183	18	53	58
DFT	--	--	--	--	--	--	--	--	--	--	10	26	6	6	11	--	--	--	--	--	13	--	12	20	--	23	26	18	26	11
RVW	19	48	--	--	--	12	52	--	--	--	12	48	--	--	--	12	52	--	--	--	--	--	--	--	--	55	200	--	--	--
RVL	3	16	--	--	--	3	15	--	--	--	2	12	--	--	--	3	15	--	--	--	--	--	--	--	--	11	58	--	--	--
NBK	3	16	--	--	--	3	16	--	--	--	3	16	--	--	--	3	16	--	--	--	--	--	--	--	--	12	64	--	--	--
NBA	3	16	--	--	--	3	16	--	--	--	3	16	--	--	--	3	15	--	--	--	--	--	--	--	--	12	63	--	--	--
ACB	9	--	3	--	--	6	--	6	--	--	6	--	6	--	--	6	--	6	--	--	--	--	--	--	--	27	--	21	--	--

* Standard units of fishing effort for each gear type were: electroshocking = 10-min duration and approximately 1000 ft long (230 v, pulsed DC, boat-mounted boom shocker); hoop nets = 48-hr sets (unbaited, nets with 1-in.-sq. mesh); gill nets = 24-hr sets (gill nets were 150 ft long by 8 ft deep and consisted of six 25-ft-long by 8-ft-deep panels having square mesh sizes of 1 to 3-1/2 in. in 1/2-in.-long increments); seines = 100-ft haul ("common sense" seine, 30 ft long by 4 ft deep having 1/8-in. delta mesh); minnow trap = 24-hr sets.

** ES = electroshocker; HN = hoop net; EG = gill net; SN = seine; MT = minnow trap.

† DFC = Lower Cracraft Dike Field; DFL = Leota Dike Field; DFT = Chicot Landing Dike Field; RVW = Walnut Point-Kentucky Bend Revetment; RVL = Lakeport Revetment; NBK = Island 88 Natural Bank; NBA = Anconia Natural Bank; ACB = Matthews Bend Abandoned Channel.

River. Gill nets placed in the river's current are subject to either being torn out by large floating or submerged objects (e.g. logs) or being filled up with debris; seining is extremely difficult along revetted and natural banks where the banks are quite steep and large objects such as fallen trees and/or irregular revetment occur underwater. Consequently, electroshocking took place across all habitats; however, gill nets were used only in quiet waters (the dike field pools and the abandoned channel) and seining was done only in the dike fields (primarily along the middle bars). Hoop nets were placed both in lotic and lentic situations. Despite these limitations placed on sampling, the pilot study collections (8,970 fish) and the intensive study samplings (14,531 fish) allowed us to effectively characterize the various habitats in terms of their fish distribution.

86. The results of these studies are presented by characterizing various habitats in terms of their fish faunas. Habitats discussed include: (a) backwaters (especially Matthews Bend), (b) natural and revetted banks, (c) dike fields (especially Lower Cracraft and Leota Dike Fields), and (d) the shallow shoreline areas. Important facets of the ecology of the individual fish species of the lower Mississippi River, as manifested by these studies, are presented in Appendix B.

Results

Backwaters (especially Matthews Bend: abandoned channel)

87. The backwaters of the lower Mississippi River consist primarily of abandoned river channels, and have been designated as chutes, abandoned channels, or oxbow lakes, depending on the size and shape of the backwater (see Cobb and Clark 1981). It is apparent from the pilot study's survey of four abandoned channels and the study of Matthews Bend during the intensive investigation that the backwaters support a diverse and interesting fish fauna. In the 1979-1980 study Matthews Bend was the only habitat in which all four species of gar, alligator (*Lepisosteus spatula*), longnose (*L. osseus*), shortnose (*L. platostomus*),

and spotted (*L. oculatus*), were collected (Table 11). Matthews Bend was also characterized by high densities of gizzard shad (*Dorosoma cepedianum*). The other clupeid species found in the lower Mississippi River, skipjack herring (*Alosa chrysochloris*) and threadfin shad (*Dorosoma petenense*), were also present in fairly large numbers at various times (Tables 11 and 12). The presence of fairly large numbers of skipjack herring in the backwaters is somewhat surprising since Buchanan (1976), Pflieger (1975), and Trautman (1981) have described the skipjack as being an inhabitant of swift waters. While it does inhabit swift areas in the lower Mississippi River, our data indicate that it also frequents backwaters in appreciable numbers. In addition to the skipjack herring collected from Matthews Bend in the intensive study, 22 skipjacks were collected from Matthews Bend during the pilot study and 35 skipjacks were captured from Lake Lee (an oxbow lake) (Table 13).

88. Threadfin shad showed an interesting occurrence pattern in Matthews Bend during the intensive study. This species was present only in September and November (absent in April and June) (Pennington, Baker, and Bond 1983). All the individuals collected in September and November were between 72 and 97 mm in total length, and are probably young-of-the-year, having been spawned in the spring.

89. A number of fishes such as carp (*Cyprinus carpio*), river carpsucker (*Carpiodes carpio*), smallmouth buffalo (*Ictiobus bubalus*), white bass (*Morone chrysops*), and freshwater drum (*Aplodinotus grunniens*) are ubiquitous throughout the lower Mississippi, being present in backwaters as well as in the main-stem river. Because of their large size these fish made up a considerable portion of the fish biomass collected in 1979 in Matthews Bend. River carpsuckers, carp, and drum were especially abundant in the backwaters investigated in 1978 (Table 13) and in the intensive study in Matthews Bend (Table 11).

90. The large catfishes present in the lower Mississippi River, the blue (*Ictalurus furcatus*), channel (*I. punctatus*), and flathead (*Pylodictis olivaris*), were all present in Matthews Bend. However, none of these ictalurids were found to be very abundant. A comparison of numerical catch per unit effort (C/f) for blue and channel catfish with

Table 11

Numbers of Fishes Collected with All Gear Types from the Abandoned Channel at Matthews Bend and the Natural Banks at Anconia and Island 88, Lower Mississippi River, April 1979 - September 1980

Species	Abandoned Channel: Matthews Bend			Natural Bank: Anconia			Natural Bank: Island 88		
	EG*	ES*	TL*	HN*	ES	TL	HN	ES	TL
Shovelnose sturgeon				2		2			
Paddlefish	3		3						
Spotted gar	28	37	65						
Longnose gar	8		8		1	1		2	2
Shortnose gar	29	4	33	1	17	18	2		2
Alligator gar	4		4						
Bowfin	1		1						
American eel				2		2	4		4
Skipjack herring	120	4	124		13	13	1	3	4
Gizzard shad	397	773	1170		120	120	7	57	64
Threadfin shad		92	92		8	8		2	2
Goldeye	3	1	4		1	1		2	2
Carp	7	26	33	1		1	1		1
Mississippi silvery minnow					1	1		1	1
Blacktail shiner					1	1	1		1
River carpsucker	40	5	45	1		1			
Highfin carpsucker	1		1						
Blue sucker				2		2			
Smallmouth buffalo	15	6	21				1	1	2
Bigmouth buffalo	5	1	6	1	1	2	1		1
Spotted sucker		1	1						
Blue catfish	8		8	13	1	14	9		9
Yellow bullhead	1		1						
Channel catfish	23	3	26	1		1	1		1
Flathead catfish		1	1	16	1	17	16		16
White bass	17	4	21	2		2	2		2
Striped bass	2		2						
Warmouth		1	1	1		1			
Orangespotted sunfish		2	2						
Bluegill	2	68	70	2		2	3	1	4
Redear sunfish	1		1						
Largemouth bass	2	15	17						
White crappie	3	12	15				3		3
Black crappie	1	8	9						
Sauger		1	1						
Freshwater drum	87	10	97	10		10	26		26
Striped mullet					2	2		3	3
	808	1075	1883	55	167	222	78	72	150

* EG = gill net; ES = electroshocker; TL = total; HN = hoop net.

Table 12

C/f* (Gill Nets) for Skipjack Herring in Matthews Bend in 1979

Date	C/f	% of Total Fishes (Numbers) Collected Which Consisted of Skipjack Herring
June 1979 (6)**	11.3	16
September 1979 (6)	3.5	10
November 1979 (6)	4.8	18

* C/f = Catch per unit effort; here C/f = mean number of fish per gill net-days (24-hr sets).
** Number of net-days sampled.

a common gear (gill nets) between Matthews Bend and the dike field pools shows that the blue catfish, in particular, is comparatively infrequent in the abandoned channel (Table 14). Flathead catfish were not commonly collected in Matthews Bend in the intensive study (Table 11) nor in the other backwaters investigated in the pilot study (Table 13). This may be a sampling artifact, however, since the placing of hoop nets in a current seemed to be the only effective means of collecting flathead catfish. Although the numbers of bullheads collected in the pilot study (Table 13) and the intensive study (Table 11) were low, it is meaningful since no bullheads were collected (in either study) in any habitat other than the backwaters.

91. At low flows Matthews Bend supported a diverse centrarchid community which was dominated by bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), and black crappie (*P. nigromaculatus*) (Tables 11, 15, and 16). The bluegill and white crappie were also the two most common centrarchids collected from backwaters in the pilot study (Table 13).

92. Since paddlefish (*Polyodon spathula*) were collected only in gill nets in these investigations, and gill nets could be used only in lentic situations, it is not possible to state that the paddlefish does not occur in lotic situations in the lower Mississippi River. However, it is apparent from the 1979 Matthews Bend data (Table 11) and the pilot

Table 13

Numbers of Fish Captured with All Usable Gear Types from Different Habitats in the Lower Mississippi River, April-December 1978

	Abandoned Channel			Oxbow Lake	Natural Bank			Revetted Bank				
Species	Matthews Bend	Moon Chute	Carolina Chute	(Lake Lee)	Anconia	Island 88	Mayersville	Cracraft	Lakeport	Mayersville	Sunnyside	Walnut Point-Kentucky Bend
Shovelnose sturgeon	1						4			1		
Paddlefish	2	2		20								
Spotted gar	3	16		3								
Longnose gar	1	1		13						2	2	
Shortnose gar	12	41	3	30			14			1		1
Bowfin	6	10	9	3								
American eel				1			6					1
Skipjack herring	22	1		35			3			12		1
Gizzard shad	586	379	48	764	1		37			32	1	19
Threadfin shad		5		7								
Goldeye	2		1				3					
Mooneye							2			4		
Stoneroller												
Goldfish										2		
Carp	20	30	11	17	5	7	42	1	2	10		11
Cypress minnow												
Silvery minnow												
Speckled chub												
Silver chub												
Emerald shiner												
River shiner												
Pugnose minnow												
Ribbon shiner												
Red shiner												
Taillight shiner												
Silverband shiner												
Spotfin shiner												
Weed shiner												
Redfin shiner												
Blacktail shiner												
Mimic shiner												
Steelcolor shiner												
Bullhead minnow												
Creek chub												
River carpsucker	210	135	18	267	3		16			5		7
Quillback	2	3		2			2					
Highfin carpsucker	1			1								

(Continued)

(Sheet 1 of 4)

Table 13 (Continued)

Species	Abandoned Channel: Matthews Bend	Abandoned Channel: Moon Chute	Abandoned Channel: Carolina Chute	Oxbow Lake (Lake Lee)	Natural Bank: Anconia	Natural Bank: Island 88	Natural Bank: Mayersville	Revetted Bank: Cracraft	Revetted Bank: Lakeport	Revetted Bank: Mayersville	Revetted Bank: Sunnyside	Revetted Bank: Walnut Point-Kentucky Bend
Blue sucker				1							1	1
Smallmouth buffalo	3	2	2	14			3		2	11	2	3
Bigmouth buffalo	2	2	1	11			4					
Black buffalo												
Spotted sucker					2							
Blue catfish	18	11	8	7	3		24		3	17	3	3
Black bullhead	1	1										
Yellow bullhead		1		2								
Brown bullhead		1										
Channel catfish	15	24	2	56	6		8		21	3	21	8
Flathead catfish	4	1	2	2	3	3	61		5	27	2	11
Blackstripe topminnow												
Mosquitofish												
Brook silverside												
Mississippi silverside												
White bass	1			2			3					1
Striped bass	7											
Warmouth		3										
Orangespotted sunfish												
Bluegill	11	17		5						2		
Longear sunfish												
Redear sunfish		2		6								
Spotted bass												
Largemouth bass	2	3		2								
White crappie	14	29		36		1	5			1		1
Black crappie												
Bluntnose darter												
Sauger	2	1		1								
Freshwater drum	90	66	8	104	7	1	192	1	1	71	1	24
Total Individuals	1038	787	113	1412	30	12	429	2	34	201	33	92
Total Species	26	26	12	27	8	4	18	2	6	16	8	14

(Continued)

(Sheet 2 of 4)

Table 13 (Continued)

Species	Dike Field: Lower Cracraft	Dike Field: Island 86	Dike Field: Leota	Dike Field: Seven Oaks	Dike Field: Walnut Point	Sandbar: Kentucky Bend Bar	Sandbar: Lakeport Towhead	Permanent Secondary Channel (American Cutoff)	Temporary Secondary Channel (Kentucky Bend Bar)	Inundated Floodplain	Borrow Pit
Shovelnose sturgeon		1				1		7			
Paddlefish											
Spotted gar											6
Longnose gar		8	11	7		3		2			
Shortnose gar		5	13	5	4	14	1				
Bowfin		1									6
American eel			1	1				1			
Skipjack herring		14	24			2	1	1	12		
Gizzard shad	1	140	936	64	4	31	94	2	98		
Threadfin shad		22	67			2	8		34		
Goldeye		2	16				2				
Mooneye			9						4		
Stoneroller				1							
Goldfish		3									
Carp	2	22	10	16	2	2	3	19	1	2	1
Cypress minnow			1								
Silvery minnow		49	17				12				
Speckled chub							2				
Silver chub		1	1				14		2		
Emerald shiner		89	37			1	18		4		
River shiner		72	108	1		3	85		101		10
Pugnose minnow		2									
Ribbon shiner		1	1			1					
Red shiner		8	16	3			1				
Taillight shiner			1								2
Silverband shiner			8			2	13		2		
Spotfin shiner			6								
Weed shiner			4				1				1
Redfin shiner		11	1				1				
Blacktail shiner		4	30	3		2	3		9		
Mimic shiner		9	4			1	10		1		
Steelcolor shiner			2								
Bullhead minnow		6	1			1	10		3		
Creek chub			1								
River carpsucker	6	33	100	18	3	9	26	2	9		
Quillback		4	3	1		1	1				
Highfin carpsucker			9				1				

(Continued)

(Sheet 3 of 4)

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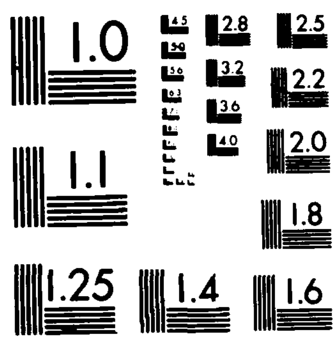

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Table 13 (Concluded)

Species	Dike Field: Lower Cracraft	Dike Field: Island 86	Dike Field: Leota	Dike Field: Seven Oaks	Dike Field: Walnut Point	Sandbar: Kentucky Bend Bar	Sandbar: Lakeport Towhead	Permanent Secondary Channel (American Cutoff)	Temporary Secondary Channel (Kentucky Bend Bar)	Inundated Floodplain	Borrow Pit
Blue sucker											
Smallmouth buffalo		4	12	4		1	2	1			
Bigmouth buffalo		5					1				
Black buffalo			1								
Spotted sucker		3		2							
Blue catfish		20	29	29	2	3	19	6	1		
Black bullhead											2
Yellow bullhead											
Brown bullhead											
Channel catfish	1	12	16	17	5	14	9	7	1		
Flathead catfish	1	12	24	21	5	4	8	13	8		
Blackstripe topminnow		1									
Mosquitofish		9	8				1		3		6
Brook silverside		111	19				1		5		1
Mississippi silverside		136	163			25	93		146		
White bass	1	62	32	2	1		21		37		
Striped bass		1	34				1		3		
Warmouth											
Orangespotted sunfish									1		3
Bluegill		8	12	3	2				2		2
Longear sunfish				1							
Redear sunfish			1								
Spotted bass		1									
Largemouth bass		22	2				1		1		3
White crappie		33	15	6	4	5	12		2		1
Black crappie		258	27				3		12		
Bluntnose darter							2				
Sauger									7		
Freshwater drum	15	59	32	83	17	32	13	23	1		
Total Individuals	27	1264	1865	288	51	160	494	84	510	2	44
Total Species	7	41	45	21	11	23	36	12	28	1	13

(Sheet 4 of 4)

Table 14

C/f* (Gill Nets) for Blue Catfish and Channel Catfish in Matthews Bend and Pools of Lower Cracraft and Leota Dike Fields

Sampling Site	Nov. 1979	Sept. 1979	Sept. 1980
	Blue Catfish		
Matthews Bend	0.00	0.83	N.S.
Lower Cracraft pools	4.00	N.S.	2.96
Leota pools	3.34	N.S.	3.41
	Channel Catfish		
Matthews Bend	1.50	0.83	N.S.
Lower Cracraft pools	0.50	N.S.	1.41
Leota pools	1.17	N.S.	4.17

* Mean number of fish per net-day (24-hr sets).
N.S. = not sampled with gill nets.

study information (Table 13 - especially Lake Lee) that paddlefish inhabit the backwaters of our study area.

93. Although some fish such as the river carpsucker, drum, and carp are ubiquitous throughout the lower Mississippi River and were therefore collected over a wide range of habitats (including the backwaters), our data indicate that a number of species are "specific" for backwaters, showing a marked preference for the lentic conditions existing in the abandoned channels and seldom being encountered elsewhere. These fishes include the spotted gar, bowfin (*Amia calva*), black bullhead (*Ictalurus melas*), brown bullhead (*I. nebulosus*), yellow bullhead (*I. natalis*), and possibly paddlefish (Figure 25). In addition, a diverse centrarchid community seems to exist only in the backwaters (Table 15).

94. Although the investigated abandoned channels were of markedly different sizes, they all contained remarkably similar faunas (Tables 11

Table 15

Centrarchid Collections in 1979-1980 in Lower Mississippi River Habitats

Species	Habitat							
	Lakeport Revetment	Walnut Point-Kentucky Bend Revetment	Anconia Natural Bank	Island 88 Natural Bank	Matthews Bend	Leota Dike Field	Lower Cracraft Dike Field	Chicot Landing Dike Field
Warmouth			✓		X_1			
Orangespotted sunfish					X			
Bluegill		X	✓	X	X	X	X	X
Longear sunfish						X_1		
Redear sunfish					X_1			
Largemouth bass		✓			X	X	X_1	
White crappie	X_1			✓	X	X	X	X
Black crappie					X	X	X	X

X = collected two or more individuals of this species from this site.

X_1 = only one fish of this species collected in this habitat throughout 1979-1980 study.

✓ = collected at this site only during April (flood conditions).

Table 16

C/f for Centrarchids in Matthews Bend in November 1979

Species	Gill Nets (6)*	Electroshocking (6)*
Warmouth	--**	0.17
Orangespotted sunfish	--	0.33
Bluegill	0.33	10.33
Redear sunfish	0.17	--
Largemouth bass	0.33	2.33
White crappie	0.17	2.00
Black crappie	--	1.33

* Numbers in parentheses are the sampling effort.
** No individuals of this species collected with this gear.

and 13). Gizzard shad, river carpsuckers, and drum were abundant at each site. In addition, bluegill and white crappie appeared to be fairly common among the lower Mississippi River backwaters. Bowfins were found at all four backwater sites in 1978 while paddlefish and spotted gar were collected at three of these four sites. Bowfin, paddlefish, and spotted gar were all captured in Matthews Bend in 1979. The backwaters' faunas are therefore similar to each other, and, as will be shown, are markedly different from the river's other habitats.

Natural and revetted banks

95. A number of species which were fairly common in the backwaters in either the pilot study or the intensive study were either absent or only rarely collected from the bank habitats. Such species include the spotted gar, bowfin, and paddlefish (Tables 11, 13, and 17). Conversely, shovelnose sturgeon (*Scaphirhynchus platorhynchus*) and blue sucker (*Cycleptus elongatus*) were commonly collected along the bank habitats in 1979 (Tables 11 and 17, Figure 25), yet not a single individual of either of these species was collected from Matthews Bend in the 1979 investigations (Table 11). The American eel (*Anguilla rostrata*) and striped mullet (*Mugil cephalus*) were also collected along

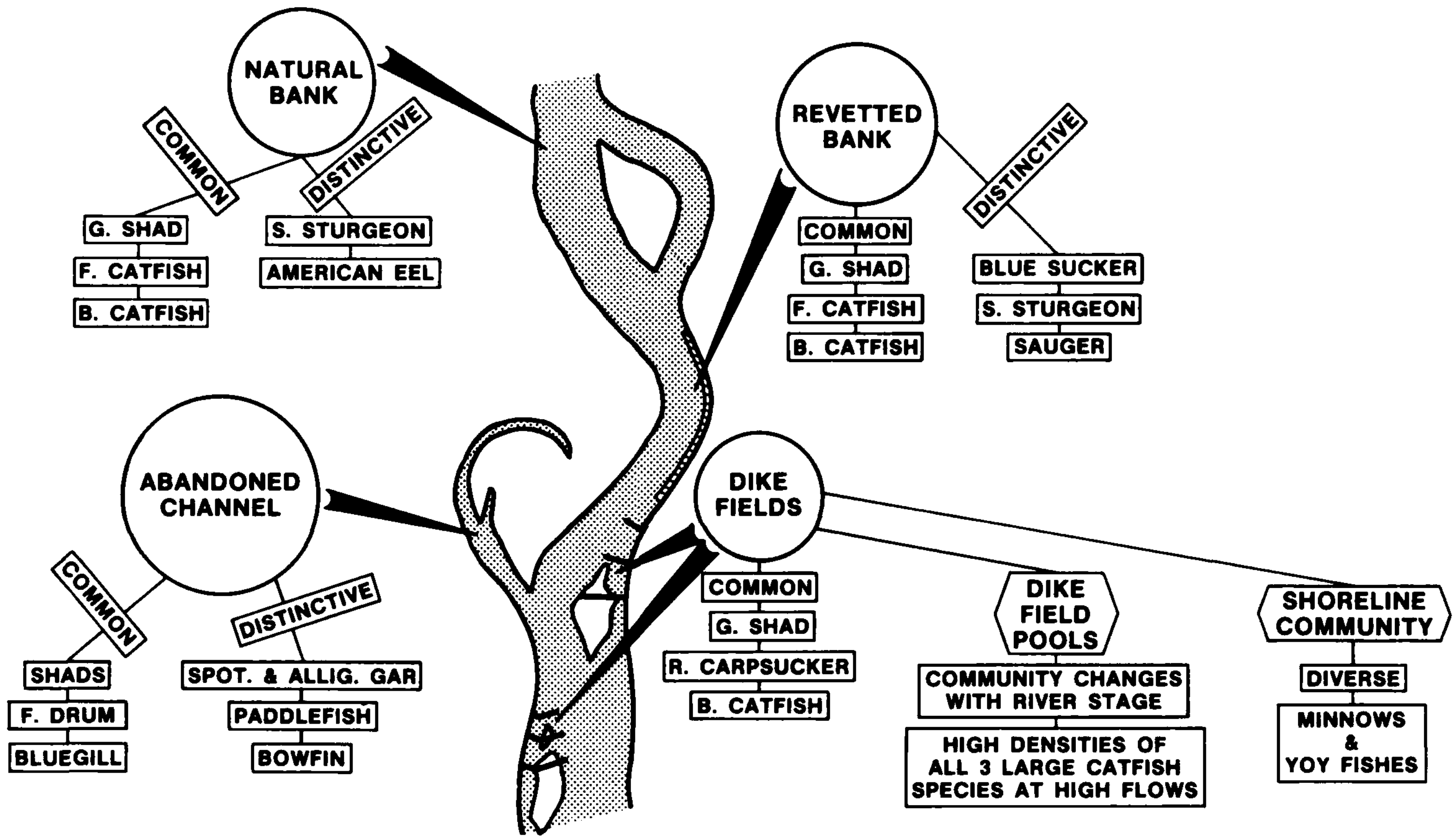

Figure 25. Schematic drawing of lower Mississippi River fish composition showing both the most common and distinctive species for the investigated habitats. Some characteristics of dike field fish communities are also shown

Table 17

Numbers of Fishes Collected with All Gear Types from the Revetted Banks at Walnut Point-Kentucky Bend and Lakeport, Lower Mississippi River, April 1979 - September 1980

	Revetted Bank: Walnut Pt-Kentucky Bend			Revetted Bank: Lakeport		
Species	HN*	ES*	TL*	HN	ES	TL
Shovelnose sturgeon	3		3	7		7
Spotted gar		4	4			
Longnose gar		7	7		1	1
Shortnose gar		10	10			
Bowfin		1	1			
American eel	7		7			
Skipjack herring	1	15	16	1	3	4
Gizzard shad	4	432	436		162	162
Threadfin shad		20	20		3	3
Goldeye	1	6	7	1	2	3
Carp	11	30	41			
River shiner		1	1			
Silverband shiner		1	1			
River carpsucker	6	12	18		1	1
Blue sucker	17	18	35	5	6	11
Smallmouth buffalo	15	20	35		2	2
Bigmouth buffalo		1	1		1	1
Blue catfish	20	40	60	12		12
Channel catfish	18		18	47		47
Flathead catfish	66	13	79	7		7
White bass		5	5			
Bluegill		3	3			
Largemouth bass		1	1			
White crappie					1	1
Sauger	4	1	5	2		2
Freshwater drum	24	19	43	8	3	11
Striped mullet		3	3			
	197	663	860	90	185	275

* HN = hoop net; ES = electroshocker; TL = total.

the river's banks in the intensive study but did not appear in any of the Matthews Bend collections. These four species were also rarely, if ever, collected from the backwaters investigated in the 1978 pilot study (shovelnose sturgeon - 1, blue sucker - 1, American eel - 1, striped mullet - none, see Table 13).

96. The ubiquitous and abundant gizzard shad was the most commonly collected species in both the revetted and natural bank habitats (Tables 11 and 17). Flathead and blue catfish were generally the next most common species collected from the bank habitats. Although their abundances may be somewhat a function of gear type (hoop nets in current are good catfish collectors), it is apparent that the catfishes are common along the bank habitats. Table 18, which compares catches of catfishes along the banks in 1979, shows that flathead and blue catfish are consistently present along the banks and are generally considerably more common than channel catfish. The two bank habitats which were heavily sampled during the pilot study showed this same trend, with a ratio from

Table 18

C/f* (Hoop Nets) for Blue, Channel, and Flathead Catfish Collected Along the Natural and Revetted Banks in 1979

Habitat	Catfish	Apr 1979	Jun 1979	Sep 1979	Nov 1979
Anconia Natural Bank	Blue	0.12	0.12	0.44	0.13
	Flathead	0.12	0.31	0.38	0.20
	Channel	0.06	--**	--	--
Island 88 Natural Bank	Blue	0.19	0.12	0.19	0.07
	Flathead	0.06	0.69	0.19	0.07
	Channel	--	0.06	--	--
Walnut Point-Kentucky Bend Revetment	Blue	0.10	0.19	0.08	0.02
	Flathead	0.04	0.60	0.50	0.17
	Channel	0.10	0.19	0.04	0.02
Lakeport Revetment	Blue	0.12	0.13	0.67	--
	Flathead	0.06	0.13	0.17	0.13
	Channel	--	3.07	--	0.07

* Mean number of fish per net (nets set for 48 hr).
** No individuals of this species collected.

the natural bank at Mayersville of 61 flatheads:24 blues:8 channels, and, at the revetted bank at Mayersville, 27 flatheads:17 blues: 3 channels (Table 13). However, it is evident from the C/f in June at Lakeport Revetment that channel catfish occasionally occur in large densities along the river's banks (Table 18).

97. Freshwater drum were also one of the most common fishes collected from the bank habitats, both in the pilot study (Table 13) and the intensive study (Tables 11 and 17). Other fish species which were fairly common in the 1979 bank collections included the blue sucker, shovelnose sturgeon, American eel, goldeye, carp, river carpsucker, smallmouth buffalo, skipjack herring, and threadfin shad. Threadfin shad were collected from the bank habitats only in April and June (none collected in September or November at any of the bank habitats; Pennington, Baker, and Bond 1983). Generally the threadfin shad collected along the banks were of a relatively large size (greater than 100 mm total length). This contrasts strongly with the threadfin shad of the abandoned channel, which were small in size and were present only in September and November.

98. Both the intensive and the pilot study showed the gars present along the banks to consist almost entirely of either shortnose or longnose (no alligator gars and a total of only four spotted gars were collected along the banks in both studies). Centrarchids were fairly uncommon in collections along the banks and were represented by bluegills, white crappies, largemouth bass, and warmouths (*Lepomis gulosus*). The striped mullet, a marine species, was collected in 1979 by electroshocking from three of the four bank habitats. Sauger, white bass, and bigmouth buffalo (*Ictiobus cyprinellus*) were also captured (in fairly small numbers) from the bank habitats in 1979.

99. A revetted vs. natural bank comparison is of interest since as of September 1980 there were 1252 km of revetted banks on the lower Mississippi River (Head of Passes, Louisiana, to Cairo, Illinois) (Pennington, Baker, and Potter 1983). A comparison of the number of species collected at the four bank habitats over the 1979 sampling occasions (Figure 26) shows very similar numbers of taxa at each site. In

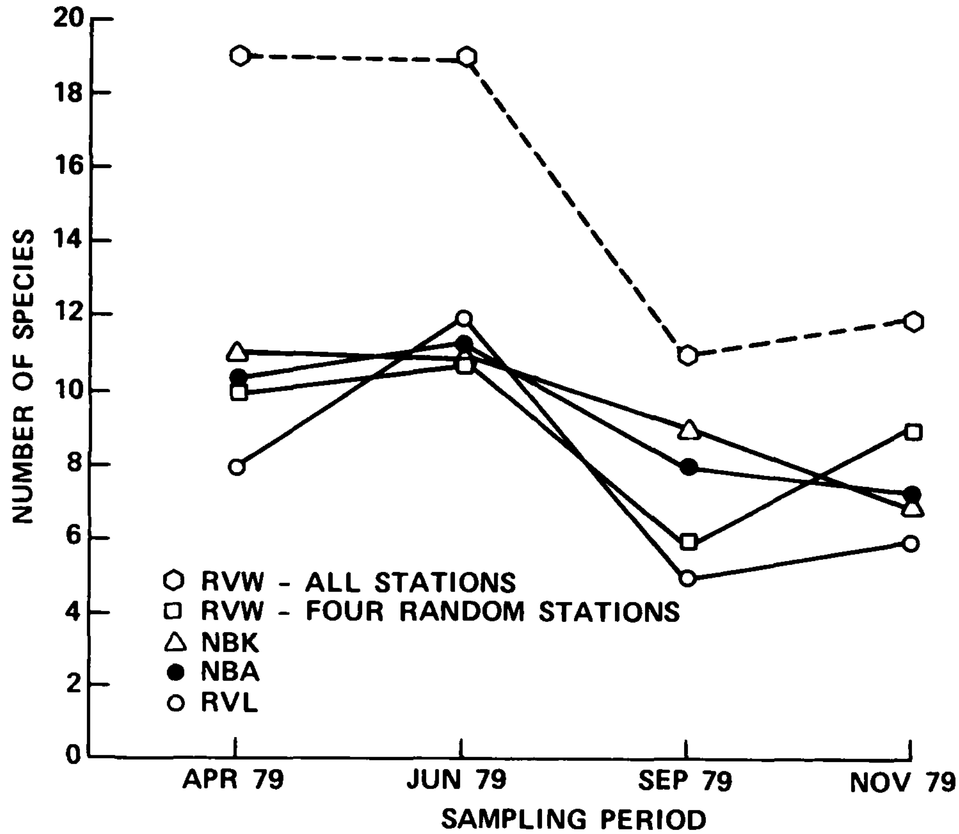

Figure 26. Comparison of number of fish species collected at the bank habitats in 1979. Four stations were chosen at random for RVW in order to equalize sample size (four stations from each habitat). RVW = Walnut Pt.-Kentucky Bend Revetment, NBK = Island 88 Natural Bank; NBA = Anconia Natural Bank; RVL = Lakeport Revetment

addition, each of the more abundant species collected from bank habitats in 1979 had individuals captured both over natural and revetted banks (Tables 11 and 17). A less common species, the sauger, is an exception since a total of seven individuals were collected over revetted banks vs. none over natural banks. However, the overall small numbers of saugers collected makes any conclusions tentative. The C/f for some species seemed to indicate some preference for either revetted or natural banks. Two of the more pronounced "preferences" were demonstrated by blue sucker and smallmouth buffalo (Pennington, Baker, and Potter 1983); both of these species appeared to show a preference for revetted

banks. Overall, however, differences in fish community composition over the two bank types seem to be minor.

Dike fields

100. The lower Mississippi River dike fields possess diverse fish faunas. Sampling with gill nets, trammel nets, hoop nets, slat traps, and seines produced 41 species from Island 86 Dike Field during the pilot study (Table 13). In the same study 45 species were collected from Leota Dike Field with gill nets, hoop nets, seines, and electroshocking. In the 1979-1980 investigation a total of 45 species were collected from Lower Cracraft Dike Field, while 46 species were captured at Leota Dike Field, and 42 at Chicot Landing Dike Field (Table 19).

101. A fortunate feature of the dike fields is the ability to employ a wide variety in gears in their sampling. Gill nets could be used at low flows in the dike field pools. In addition, seines were used to sample the shallow shoreline community present along each side of the dike field middle bars. Seining resulted in the collection of a large number of minnows and other small fishes which inhabit the shallow areas along shorelines. Data from the seining will be presented later in the "Shallow shoreline community" results.

102. Three important attributes of fish communities are composition, diversity (number of taxa in this case), and density. Although different gears were used, and varying numbers of samples were taken in the dike fields over the various sampling dates due to changing flow conditions, the gears employed and sampling efforts were virtually identical at Leota and Lower Cracraft Dike Fields within each of the sampling dates. This permitted a comparison of the two dike fields in terms of the attributes mentioned above. Gill net data (Table 20) from November 1979 show that gizzard shad, blue catfish, river carpsucker, and channel catfish ranked first, second, fourth, and fifth in abundance at Leota, while the same species ranked first, second, fourth, and sixth, respectively, at Lower Cracraft. In September 1980 the top six species collected with gill nets at Leota were gizzard shad, river carpsucker, channel catfish, blue catfish, freshwater drum, and carp; five of these species were within the six most abundant species collected at

Table 19

Numbers of Fishes Collected with All Gear Types from Leota, Lower Cracraft, and Chicot Landing Dike Fields, Lower Mississippi River, April 1979 - September 1980

Species	Dike Field: Leota						Dike Field: Lower Cracraft						Dike Field: Chicot Landing					
	HN*	EG*	ES*	MT*	SN*	TL*	HN	EG	ES	MT	SN	TL	HN	EG	ES	MT	SN	TL
Shovelnose sturgeon	2					2	2					2						
Paddlefish		1				1		5				5						
Spotted gar			3			3			1			1						
Longnose gar	6	3	8			17			2			2		7				7
Shortnose gar	4	7	6			17	1	15	4			20		8	4		1	13
Alligator gar			1			1			1			1						
American eel	1					1	4		5			9						
Skipjack herring	1	1	30		1	33		41	50		6	97		1	3		2	6
Gizzard shad	7	284	456		55	802	3	910	1257		25	2195		107	54		30	191
Threadfin shad		4	56		46	106			81		6	87			1		36	37
Goldeye		13	7			20		43	6		9	58			5			5
Mooneye			2		5	7			2		1	3			2			2
Carp	6	15	35			56	10	2	26			38		10	4			14
Mississippi silvery minnow			7		29	36			4		119	123			1		30	31
Speckled chub					31	31					81	81					54	54
Silver chub			2		7	9			1		8	9			1		33	34
Emerald shiner			1		234	235			2		269	271			8		84	92
River shiner			1	12	442	455			2	5	882	889				6	115	121
Pugnose minnow																	1	1
Spottail shiner											1	1					1	1
Red shiner			1		108	109					12	12					13	13
Taillight shiner																2		2
Silverband shiner				7	82	89			2	2	126	130				4	636	640
Weed shiner																	2	2
Blacktail shiner					228	228			3	3	74	80					307	307
Mimic shiner					30	30					12	12					29	29
Bullhead minnow				7	37	44				2	7	9				4	183	187
River carpsucker	15	61	43		17	136	5	57	29		28	119	3	50	3		8	64
Quillback					1	1		1	2			3	1					1
Highfin carpsucker		1	1			2		2	1			3			2		1	3
Blue sucker	2					2	8	1	1			10			1			1
Smallmouth buffalo	6	9	10		16	41	3	5	8		6	22	1	4	1			6
Bigmouth buffalo			2			2			5			5		2			1	3
Blue catfish	34	61	68	1	1	165	46	98	176			320	4	39	42		3	88
Channel catfish	38	57	16		1	112	44	30	8	2	18	102		8	1	7	25	41
Flathead catfish	99	9	12			120	114	1	8			123	8	1	1			10
Blackspotted topminnow					3	3												
Mosquitofish					13	13					1	1					10	10
Brook silverside					19	19					7	7					12	12
Inland silverside					74	74					189	189					45	45
White bass		5	12		27	44	5	23	24		47	99		4			4	8
Striped bass		1	1		1	3		3	2		1	6					1	1
Warmouth																1	1	2
Bluegill	13		8		11	32	12		5		2	19				5	72	77
Longear sunfish	1					1												
Largemouth bass			4			4			1			1						
White crappie	10	7	8			25	10	3	13			26		1	1			2
Black crappie	3	1	2		1	7	5		3		4	12	9	1				10
Sauger		12	14		8	34	1	11	12		7	31	1		2			3
Freshwater drum	34	28	22		15	99	44	31	22		1	98	6	29	2		10	47
Striped mullet			3			3		1	2			3						
Fish not identified to species:																		
Dorosoma spp.																	2	2
Esox spp.																	1	1
Hybopsis spp.					3	3												
Notropis spp.					99	99					63	63					17	17
Cyprinidae																	3	3
Carpiodes spp.																	1	1
Catostomidae											5	5						
Morone spp.			1		18	19					2	2						
Lepomis spp.					2	2				1		1					68	68
Centrarchidae																	4	4
	282	580	843	27	1665	3397	317	1283	1771	15	2019	5405	33	272	139	29	1666	2339

* HN = hoop net; EG = gill net; ES = electroshocker; MT = minnow trap; SN = seine; TL = total.

Table 20

Gill Net Catches from Dike Field Pools in 1979 and 1980

Date	Site	Rank	Common Name	No. Collected	% of Total Collection
		Fishes Collected			
November 1979	Leota (6)*	1	Gizzard shad	119	66.1
		2	Blue catfish	20	11.1
		3	Sauger	9	5.0
		4	River carpsucker	8	4.4
		5	Channel catfish	7	3.9
		7	Freshwater drum	4	2.2
		7	Smallmouth buffalo	4	2.2
		8	Goldeye	3	1.7
		12	Skipjack herring	1	0.6
		12	White crappie	1	0.6
		12	Flathead catfish	1	0.6
		12	White bass	1	0.6
		12	Shortnose gar	1	0.6
		12	Carp	1	0.6
November 1979	Lower Cracraft (12)	1	Gizzard shad	237	64.6
		2	Blue catfish	48	13.1
		3	Skipjack herring	26	7.1
		4	River carpsucker	16	4.4
		5	White bass	15	4.1
		6	Channel catfish	6	1.6
		8	Sauger	4	1.1
		8	Goldeye	4	1.1
		10	Freshwater drum	3	0.8
		10	Smallmouth buffalo	3	0.8
		11	Paddlefish	2	0.5
		13	Quillback	1	0.3
		13	Blue sucker	1	0.3
		13	Highfin carpsucker	1	0.3
September 1979	Chicot Landing (6)	1	Gizzard shad	7	33.3
		2	Blue catfish	4	19.0
		3	Carp	3	14.3
		5	Freshwater drum	2	9.5
		5	Shortnose gar	2	9.5
		5	Longnose gar	2	9.5
		7	Smallmouth buffalo	1	4.8
September 1980	Leota (12)	1	Gizzard shad	165	41.3
		2	River carpsucker	53	13.3
		3	Channel catfish	50	12.5
		4	Blue catfish	41	10.3
		5	Freshwater drum	24	6.0
		6	Carp	14	3.5

(Continued)

* Numbers in parentheses indicate the number of gill nets fished (24-hr sets).

Table 20 (Concluded)

Date	Site	Fishes Collected Rank	Common Name	No. Collected	% of Total Collection
September 1980 (cont.)	Leota (12)	7	Goldeye	10	2.5
		8	Flathead catfish	8	2.0
		10	White crappie	6	1.5
		10	Shortnose gar	6	1.5
		11	Smallmouth buffalo	5	1.3
		13	White bass	4	1.0
		13	Threadfin shad	4	1.0
		15	Sauger	3	0.8
		15	Longnose gar	3	0.8
		18	Striped bass	1	0.3
		18	Paddlefish	1	0.3
		18	Highfin carpsucker	1	0.3
		18	Black crappie	1	0.3
September 1980	Lower Cracraft (17)	1	Gizzard shad	673	73.5
		2	Blue catfish	50	5.5
		3	River carpsucker	41	4.5
		4	Goldeye	39	4.3
		5	Freshwater drum	28	3.1
		6	Channel catfish	24	2.6
		8	Skipjack herring	15	1.6
		8	Shortnose gar	15	1.6
		9	White bass	8	0.9
		10	Sauger	7	0.8
		12	White crappie	3	0.3
		12	Striped bass	3	0.3
		12	Paddlefish	3	0.3
		15	Smallmouth buffalo	2	0.2
		15	Carp	2	0.2
		17	Flathead catfish	1	0.1
		17	Highfin carpsucker	1	0.1
		17	Striped mullet	1	0.1
September 1980	Chicot Landing (12)	1	Gizzard shad	100	39.8
		2	River carpsucker	50	19.9
		3	Blue catfish	35	13.9
		4	Freshwater drum	27	10.8
		5	Channel catfish	8	3.2
		6	Carp	7	2.8
		7	Shortnose gar	6	2.4
		8	Longnose gar	5	2.0
		9	White bass	4	1.6
		10	Smallmouth buffalo	3	1.2
		11	Bigmouth buffalo	2	0.8
		14	Skipjack herring	1	0.4
		14	White crappie	1	0.4
		14	Flathead catfish	1	0.4
		14	Black crappie	1	0.4

Lower Cracraft (using gill nets) for its September 1980 sampling (Table 20). Similarly, seining, hoop netting, and electroshocking results show similar fish compositions at both dike fields (Table 19). Figure 27 shows that, per date, the number of taxa and number of individuals collected at each of the two dike fields were remarkably similar. This is somewhat surprising since the dike fields themselves are quite different. Leota is much shallower than Lower Cracraft and lacks the deep scour holes which are present below each of the dikes at Lower Cracraft. Yet, in terms of composition, diversity, and density, they seem to be very similar.

103. Physical conditions within the dike field pools vary greatly as a function of river stage. With river stage at approximately 28 ft in June 1979, the dike field middle bars were emergent but the dikes themselves remained submerged and a strong current moved through the

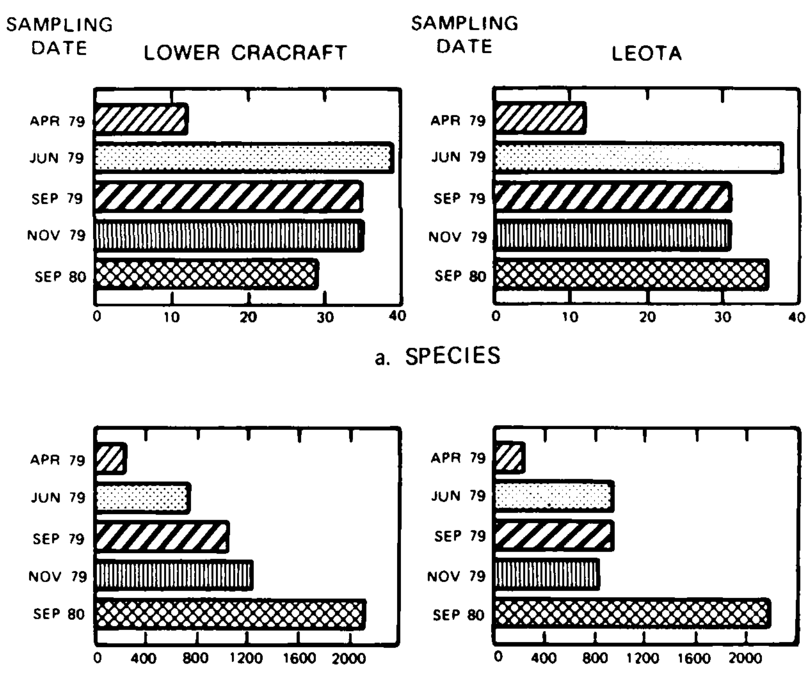

Figure 27. Comparison of fish collection data from Lower Cracraft and Leota Dike Fields showing total number of species and total number of individuals (all gears) collected for each sampling date. Various patterned bars are used for contrast only

dike fields. Hoop net data show that large numbers of blue, channel, and flathead catfish were present within the dike fields at this time (Figures 28 and 29). Various combinations of the three species were captured in the nets, and it was not unusual to collect all three species within a single hoop net. Freshwater drum were also abundant in the hoop nets placed within the dike fields, and blue sucker, shovelnose sturgeon, American eel, river carpsucker, smallmouth buffalo, and carp were fairly common. During the June sampling the catch from hoop nets on the river side of the middle bar consisted of the three catfish species, drum, river carpsuckers, and smallmouth buffaloes, and therefore indicated that at fairly high flows faunal composition outside the middle bar is similar to that within the dike field "pools."

104. Electroshocking the same dike field areas over the June sampling period produced a somewhat different subset of fish than had been collected using hoop nets. Electroshocking showed gizzard shad to be abundant within the dike field pools, even at this fairly high river stage (Table 19). Other species which were commonly collected within the pools of Leota and Lower Cracraft Dike Fields using electroshocking included drum, river carpsucker, white bass, sauger, carp, and threadfin shad. As in the case of the revetted and natural banks, the threadfin shad collected in June by electroshocking (from the dike fields) were all of a relatively large size (greater than 100 mm).

105. Gill netting within Lower Cracraft, Leota, and Chicot Dike Fields at low flows (November 1979 and September 1980) showed that gizzard shad continued to be the most abundant fish within the now quiescent pools (Table 20). Blue catfish, river carpsucker, channel catfish, and freshwater drum were abundant in gill net catches from the pools of all three dike fields in both of the low flow samplings, with shortnose gar, smallmouth buffalo, carp, and white bass also commonly collected. Electroshocking the pools on the same dates produced similar results to that of the gill netting with the exception that electroshocking showed threadfin shad to be abundant within the dike field pools at low flows (threadfin were too small to be readily caught in the gill nets). The threadfin shad collected in the dike fields at this time were all of

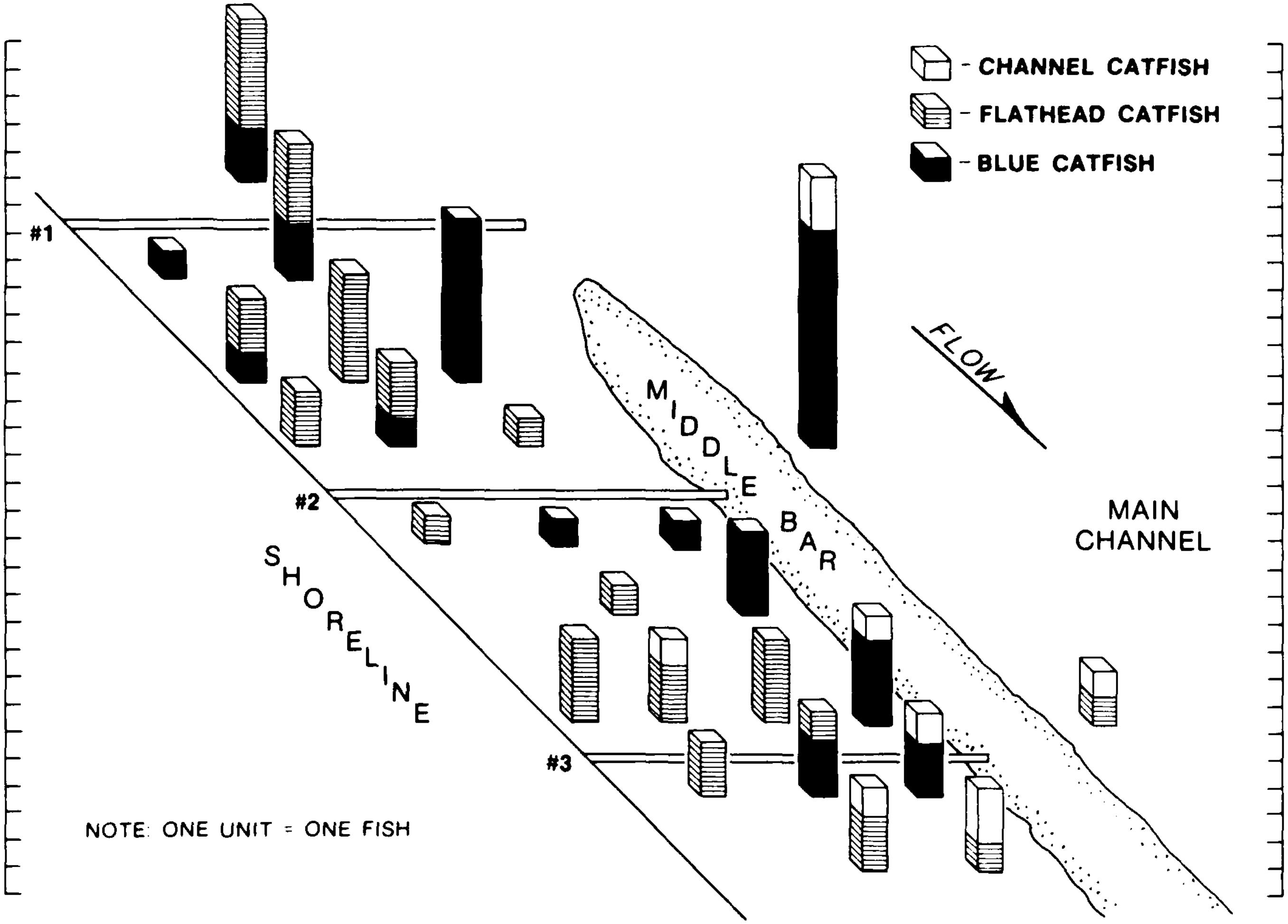

Figure 28. Hoop net catches (48-hr sets) of catfish in Lower Cracraft Dike Field on 20 June 1979. Each "column" represents the catch of a single hoop net

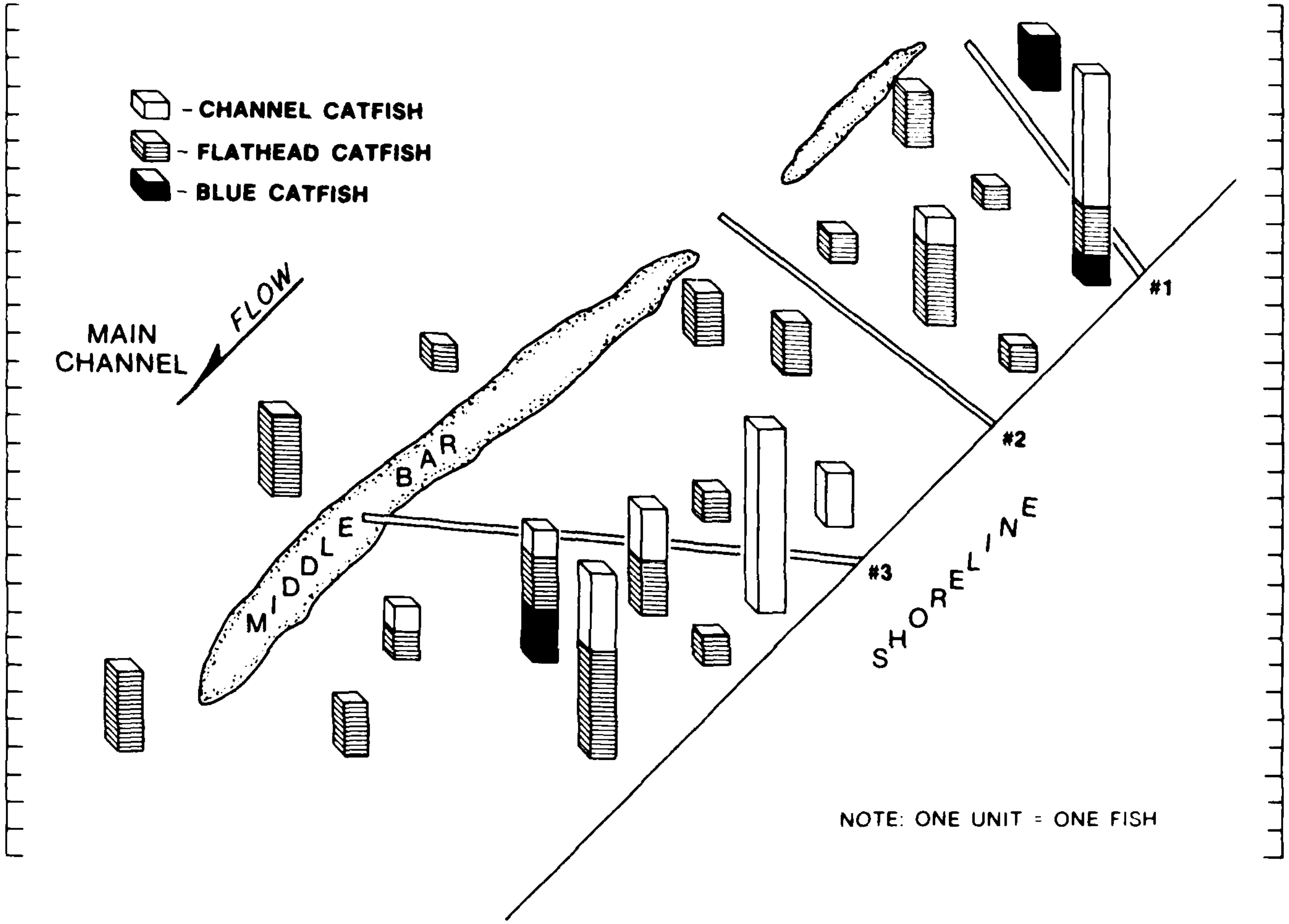

Figure 29. Hoop net catches (48-hr sets) of catfish in Leota Dike Field on 22 June 1979. Each "column" represents the catch of a single hoop net

small size (less than 100 mm in total length), i.e., similar to the threadfin shad collected in the abandoned channel during September. Threadfins preferred the pooled quiet water on the inside of the middle bars rather than the river side.

106. Blue catfish exhibited an interesting distributional pattern in September 1980 at both Leota and Lower Cracraft Dike Fields. Although gill netting showed blue catfish to be common in the dike field pools (Table 20) (gill nets were set only inside the pools), electroshocking of the entire dike field areas showed markedly higher numbers of blue catfish on the river side of the middle bars than inside the dike field pools (Figures 30 and 31). Although this phenomenon occurred at both dike fields in September of 1980, a similar pattern was not observed in November 1979 at either of the dike fields.

107. Hoop nets placed in the quiet waters of the dike field pools at low river stage proved to be inefficient in collecting catfish (which we knew to be present from the gill net data). Although the lack of current precluded the capture of catfish, the hoop nets in these quiescent waters served as attractants for centrarchid fishes and showed that bluegills, white crappies, and black crappies are present within the dike field pools at low river stages. Electroshocking and hoop netting the outside of the middle bars at low flow showed that gizzard shad, the three catfish species, river carpsuckers, and drum continued to be the dominant species in this area, as they had at higher flows.

Shallow shoreline community

108. Seining in the 1979-1980 study took place in the dike fields, with efforts concentrated along both sides (dike field pool side and river side) of the middle bars. Dike field middle bars were also seined in the pilot study along with other shallow shoreline areas occurring along river sandbars. Seining produced diverse collections of minnows, other small fishes, and young-of-the-year fishes of several families (Figure 25). Besides the young-of-the-year fishes, seine collections from both studies included representatives of the families Cyprinidae, Cyprinodontidae, Poeciliidae, Atherinidae, and Percidae (Tables 13 and 19).

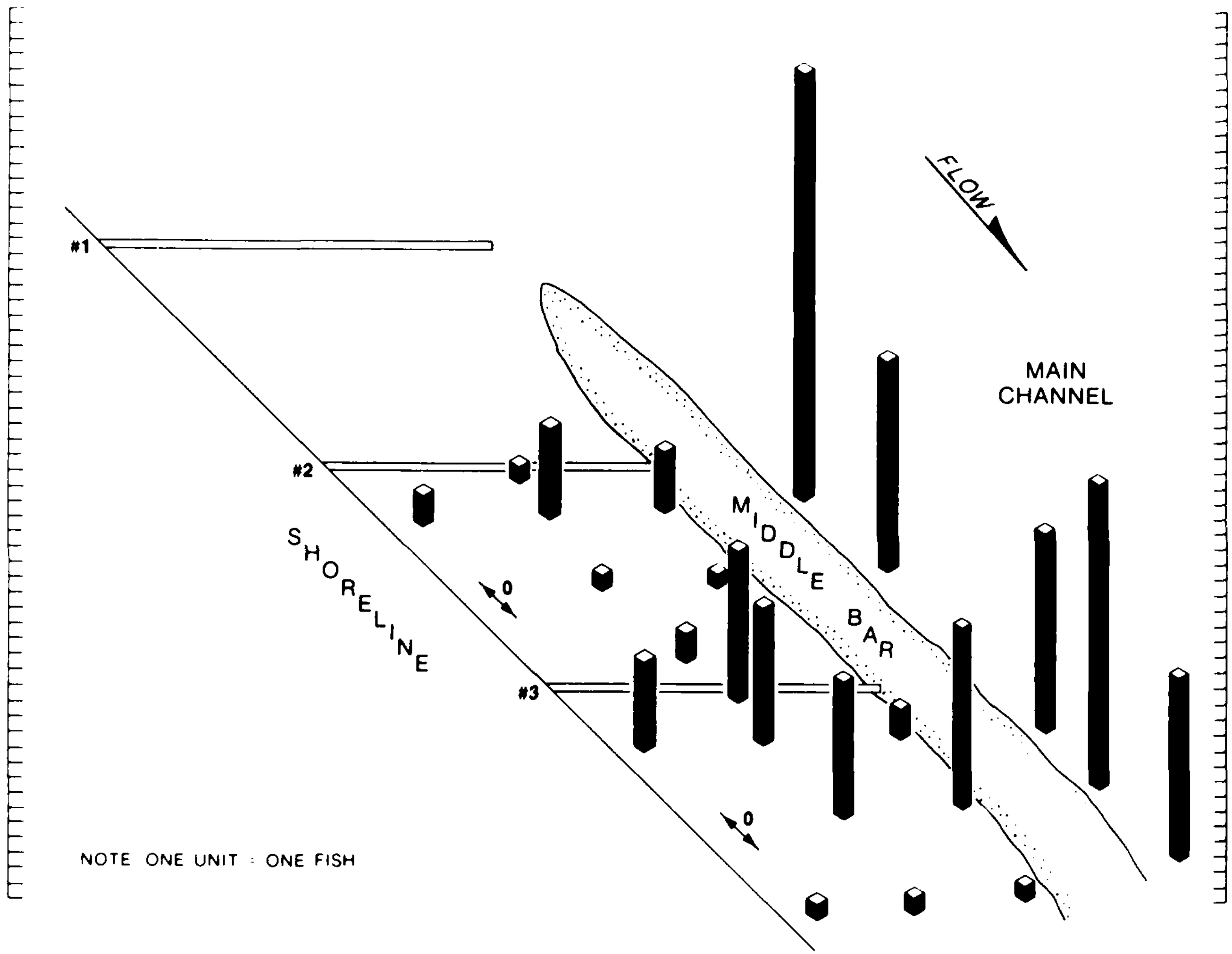

Figure 30. Catch of blue catfish per electroshocking transect at Lower Cracraft Dike Field on 8 September 1980. ←0→ represents electroshocking transects in which no blue catfish were collected

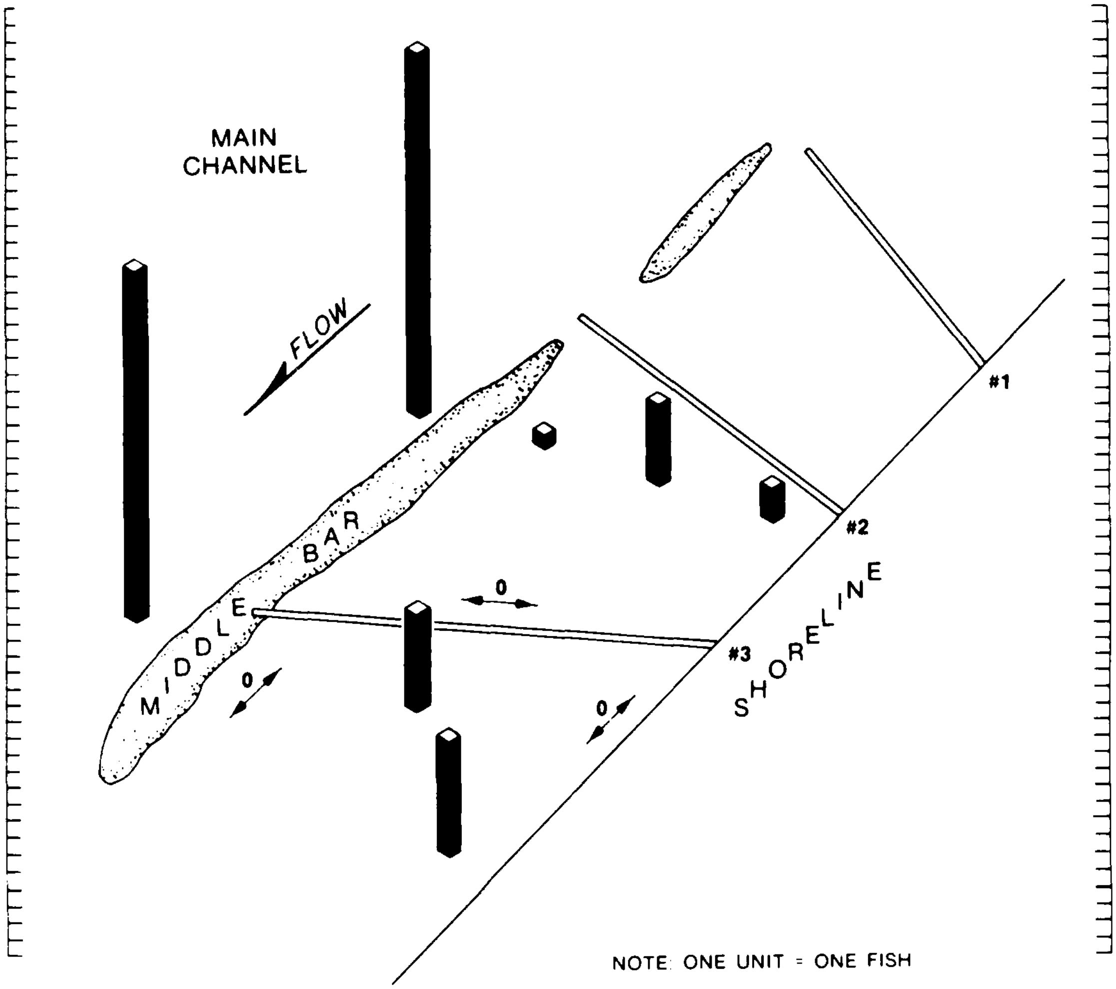

Figure 31. Catch of blue catfish per electroshocking transect at Leota Dike Field on 11 September 1980. ← 0 → represents electroshocking transects in which no blue catfish were collected

109. The river shiner (*Notropis blennius*), emerald shiner (*N. atherinoides*), silverband shiner (*N. shumardi*), and blacktail shiner (*N. venustus*) were the most common species in seine hauls along the dike field middle bars in 1979-1980 (Table 21). The river shiner was the most abundant species on six of the ten sampling "occasions" (Table 21), with the silverband shiner most abundant on two occasions, and the emerald shiner and blacktail shiner each most abundant for one sampling event. River shiner, emerald shiner, and silverband shiner were all within the top five of "minnow-like" species collected by seining in five of the ten sampling occasions.

Table 21

Most Abundant Fishes in Dike Field Seine Hauls, 1979-1980*

June 1979	September 1979	November 1979	September 1980
	Lower Cracraft Dike Field		
River shiner (27)*	River shiner (60)	River shiner (49)	Emerald shiner (30)
Mississippi silvery minnow (25)	Inland silverside (10)	Silverband shiner (16)	River shiner (24)
Silverband shiner (16)	Emerald shiner (9)	Speckled chub (14)	Inland silverside (16)
Inland silverside (3)	Mississippi silvery minnow (6)	Emerald shiner (7)	Blacktail shiner (9)
Mimic shiner (3)	Silverband shiner (5)	Blacktail shiner (5)	Silverband shiner (3)
	Leota Dike Field		
River shiner (39)	River shiner (44)	River shiner (43)	Blacktail shiner (28)
Mimic shiner (8)	Emerald shiner (21)	Emerald shiner (18)	Emerald shiner (14)
Silverband shiner (3)	Silverband shiner (5)	Speckled chub (11)	Red shiner (13)
Bullhead minnow (3)	Bullhead minnow (4)	Blacktail shiner (6)	Inland silverside (7)
Blacktail shiner (3)	Central silvery minnow (4)	Inland silverside (6)	River shiner (6)
	Chicot Landing Dike Field		
	Silverband shiner (23)		Silverband shiner (40)
	Bullhead minnow (22)		Blacktail shiner (22)
	Emerald shiner (6)		River shiner (17)
	Speckled chub (6)		Bullhead minnow (4)
	Blacktail shiner (6)		Emerald shiner (4)

* Numbers in parentheses indicate percent of all fish collected in seines which belonged to that species. Although percentages were determined from all fish collected by seining for that sampling occasion, only minnow or "minnow-like" fishes are shown in the rankings, i.e. young-of-the-year of other species are not shown in rankings.

110. Another abundant fish in seine collections was the inland silverside (*Menidia beryllina*) (Table 21). Another silverside, the brook silverside (*Labidesthes sicculus*), was also present in seine hauls, but the inland silverside was much more common. Other species such as the weed and taillight shiners (*N. texanus* and *N. maculatus*, respectively), the pugnose minnow (*N. emiliae*), and the blackspotted topminnow (*Fundulus olivaceus*) were all much less common, being represented by three or less individuals in the 1979-1980 collections. The taillight shiner was collected only in minnow traps, i.e. not in the seine hauls.

111. In addition to serving as a habitat for minnow and "minnow-like" fishes, the shallow shoreline areas serve as nursery areas for young-of-the-year white bass, river carpsuckers, smallmouth buffalo, freshwater drum, goldeyes, and saugers. This is particularly apparent in June when these fish, which have been spawned earlier in the year, reach seinable size and locate themselves in these shallow areas (see seining data, particularly June, in Pennington, Baker, and Bond 1983).

Discussion and Ecological Implications

112. The fish fauna of the lower Mississippi River (Cairo, Illinois, to Head of Passes) has some pronounced differences from that of the upper (upriver of the confluence of the Missouri and Mississippi Rivers) and middle Mississippi (from the confluence of the Missouri and Mississippi Rivers to Cairo, Illinois) (Smith, Lopinot, and Pflieger 1971). The principal factors causing these differences are the impoundment of the upper Mississippi (vs. the free-flowing middle and lower Mississippi) and the influences of the Mississippi's two major tributaries, the Missouri and the Ohio. The shovelnose sturgeon, blue sucker, and blue catfish have all suffered major declines in abundance in the upper Mississippi River in recent history (Pflieger 1975). In contrast, all three of these species appear to be present in sizable numbers in the lower Mississippi River. The shovelnose sturgeon and blue sucker are fairly common in swift current areas (along banks and in the

dike fields at high river stages) in our study area. The blue catfish is abundant in the lower Mississippi and was often one of the most common species collected in our investigations. Our data and that of Pflieger's (1975) show the shovelnose sturgeon, blue sucker, and blue catfish to prefer swift-current areas; such areas are in abundance in the lower Mississippi.

113. The Missouri River exerts a strong influence on the fish fauna of the middle Mississippi while the Ohio strongly affects the fish composition of the lower Mississippi (Smith, Lopinot, and Pflieger 1971). The Missouri contributes a number of species to the Mississippi which are then a regular component of the fish community of the middle Mississippi. Such species include the pallid sturgeon (*Scaphirhynchus albus*), the western silvery minnow (*Hybognathus argyritis*), the plains minnow (*Hybognathus placitus*), the sturgeon chub (*Hybopsis gelida*), the flathead chub (*Hybopsis gracilis*), and the sicklefin chub (*Hybopsis meeki*) (Smith, Lopinot, and Pflieger 1971). In terms of the Mississippi River these species are apparently fairly well restricted to the middle Mississippi since not a single individual of any of these species was collected in our investigations.* In contrast, Smith, Lopinot, and Pflieger (1971) have reported that in the Mississippi, near the mouth of the Ohio River, there is a sharp increase in the abundance of species such as skipjack herring, threadfin shad, silverband shiner, mimic shiner, and inland silverside. These five species were all very common in our study area.

114. The swiftly moving waters of the lower Mississippi have provided ample habitat for current-seeking fishes such as shovelnose sturgeon, blue sucker, and blue catfish. In addition, Corps construction practices (levees, river cutoffs, revetments, and dikes) have favored a swiftly moving, high energy system. In this light, the backwaters of the Mississippi are quite important since they furnish a habitat with very different conditions than those of the main-stem

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* NUS Corporation (1974) reported one pallid sturgeon and two sicklefin chubs from their lower Mississippi River studies.

river. Our investigations showed a number of fish species that are restricted to backwater habitats. Such species include the black, brown, and yellow bullheads, bowfin, spotted gar, and young threadfin shad. Other fishes such as the bluegill, largemouth bass, white and black crappie, paddlefish, and alligator gar showed a marked preference for backwater areas. Protection of the backwaters is necessary for the success of these species in the lower Mississippi River ecosystem.

115. Protection of the backwaters that presently exist is especially important since backwaters are in such relatively short supply in the lower Mississippi River. Rivers such as the Ohio have a large number of tributaries; as these tributaries flow into the river the tributaries are "backed up" forming large and numerous backwater areas. Tributaries are infrequent along the lower Mississippi and consist mostly of large rivers (e.g., there are no tributaries entering the Mississippi within the 60-mile-long 1978-1979 fish study area). The backwaters that do exist consist of variously sized abandoned channels (chutes, abandoned channels, and oxbow lakes). These abandoned channels possess a unique subset of fishes within the lower Mississippi River system, along with ubiquitous fishes such as gizzard shad, drum, river carpsucker, smallmouth buffalo, and channel catfish.

116. The placement of dikes and revetments along the river has prevented channel meandering by locking the river into a permanent alignment. Since channel meandering is necessary for abandoned channels to form, abandoned channels are only rarely created now (Nunnally and Beverly 1984). Unfortunately, the ultimate fate of all the present abandoned channels found between the levees of the lower Mississippi River is to completely fill in (Gagliano and Howard 1984). Therefore, abandoned channel habitats will be lost over time and not replaced.

117. The natural bank-revetted bank comparison showed only minor differences in species composition. In fact, a few species (sauger, blue sucker, and smallmouth buffalo) seemed to "prefer" revetted banks to natural banks. Although compositional differences were minor, natural and revetted banks may not necessarily be of equal "value" to

fishes. The presence of fish near either bank type may depend somewhat on the movement of fish to and/or from other habitats.

118. Dike fields were consistently shown (in both the pilot and intensive studies) to possess diverse fish faunas. This diversity is a product of physical structure (the dike field middle bars and the dike structures themselves) and the varying of physical conditions within the dike fields as a result of changing river stages (Figure 25). The middle bars furnish a large, shallow "shoreline" area which is populated by a diverse and abundant community of minnows and other small fishes. Such areas are also extensively used in June by young-of-the-year of a number of species, including white bass, river carpsucker, smallmouth buffalo, freshwater drum, goldeye, and sauger. Changing physical conditions within the dike field pools allow for a diverse fauna when viewed over the range of river stages. For example, during fairly high river stages (June 1979) strong currents existed through the pools, and the three large catfish species were abundant, along with river carpsuckers and the rheophilic blue sucker. At low flows the then quiescent pools were colonized not only by ubiquitous species such as gizzard shad, river carpsucker, carp, channel catfish, and drum, but also by young-of-the-year threadfin shad and some centrarchid species (bluegill, white and black crappie); i.e. some compositional similarity existed between the abandoned channel and the dike field pools.

119. Unfortunately, some dike fields, as presently constructed in the lower Mississippi River, may have limited life expectancies as aquatic habitats. They may accrete sediments, have their middle bars colonized by willows and cottonwoods, and then fill in, thereby eliminating the pools and also greatly reducing the shoreline area available for colonization by the shoreline community of fishes; i.e. an "active" dike field has the river shoreline and the inside (pool side) and outside (river side) of the middle bars as available habitat; a "filled in" dike field has only a river shoreline. Engineering designs that would maintain dike fields as aquatic habitats should be considered for use in the lower Mississippi River if filling of the dike field pools occurs.

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APPENDIX A: SEDIMENT PARTICLE-SIZE CLASSIFICATION*

Sediment-Substrate	Particle Size mm	US Standard Sieve Series
Boulder	>256	
Rubble	64-256	
Coarse gravel	32-64	
Medium gravel	8-32	
Fine gravel	2-8	10
Coarse sand	0.5-2	35
Medium sand	0.25-0.5	120
Fine sand	0.125-0.25	230
Very fine sand	0.0625-0.125	
Silt-mud	0.0039-0.0625	
Clay	<0.0039	

* This table was adapted from a soil particle-size classification scheme presented by the US Environmental Protection Agency (1973).

APPENDIX B: FISHES OF THE LOWER MISSISSIPPI RIVER--AUTECOLOGY

1. The following section is an autecological treatment of the fishes of the lower Mississippi River, including comparisons of their distribution in the lower Mississippi River to that of other large rivers. In this section the fish distribution and abundance data, when not directly referenced, are presented in Tables 11, 13, 17, and 19 of the main text. The same data set is presented for the 1979-1980 study in Pennington, Baker, and Bond (1983), and includes a breakdown by sampling date.

Family Acipenseridae - Sturgeons

2. The shovelnose sturgeon (*Scaphirhynchus platorhynchus*) was fairly commonly collected in the 1979-1980 study with hoop nets placed along both revetted banks and Anconia Natural Bank. This species was also collected from the dike field pools, but only at higher flows (April and June 1979) when strong currents moved through the dike fields. Our collection records therefore agree with those of Pflieger (1975) who indicated that "the shovelnose sturgeon inhabits the open channels of large rivers [where] it lives on the bottom, often in areas of swift current." Although the shovelnose is the most abundant sturgeon in the Missouri and upper Mississippi Rivers, its numbers have declined greatly in these rivers since 1900 (Pflieger 1975). Our data indicate, however, that the shovelnose sturgeon is fairly common in the swift-water habitats of our lower Mississippi River study area. Shovelnose sturgeon were also fairly commonly collected by NUS Corporation (1974) in a lower Mississippi River investigation between river miles 400-410.

3. There has recently been considerable interest in the status of the pallid sturgeon (*Scaphirhynchus albus*), whose range includes the lower Mississippi River (Kallemeyn 1983). Although 16 shovelnose sturgeons were collected in the 1979-1980 study, along with 15 individuals

of the same species in the pilot study, no pallid sturgeons were collected in either of the EWQOS fish investigations.

Family Polyodontidae - Paddlefish

4. Paddlefish (*Polyodon spathula*) were collected only with gill nets (1979-1980 study) and trammel nets (pilot study). Paddlefish were collected in 1979-1980 in Matthews Bend (the abandoned channel) and occasionally in the dike field pools. In the pilot study paddlefish were collected in Matthews Bend, in Moon Chute (another abandoned channel), and in Lake Lee (an oxbow lake connected by a chute to the river). Paddlefish have been characterized as inhabiting sluggish backwaters and oxbow lakes of large rivers (Buchanan 1976). Since gill nets and trammel nets were set almost exclusively in lentic situations, we cannot state that paddlefish do not frequent lotic areas. It is apparent, however, that paddlefish are present in the backwaters and abandoned channels of the lower Mississippi River.

Family Lepisosteidae - Gars

5. The lower Mississippi River has four species of gars: alligator (*Lepisosteus spatula*), shortnose (*L. platostomus*), spotted (*L. oculatus*), and longnose (*L. osseus*). The alligator gar is present in lesser numbers than the other three species; only six alligator gars were collected over the 1979-1980 study, four of which were collected in the abandoned channel (Matthews Bend). The spotted gar has a more limited distribution (habitat-wise) than the shortnose and longnose gars. Not including the April high flow period, no spotted gars were collected in the 1979-1980 study from any of the natural or the revetted banks. However, over the same study period (not including April) a total of 27 shortnose and 11 longnose gars were collected from the bank habitats. From the June 1979, September 1979, November 1979, and September 1980 samplings in the dike fields we collected a total of 75 gars: 48 shortnose, 26 longnose, and only 1 spotted.

6. All four gar species were collected in Matthews Bend during the intensive study. Gill net and electroshocking data show that the shortnose and spotted were the most common gars in this habitat.

Family Amiidae - Bowfin

7. Only two individuals of the bowfin (*Amia calva*) were collected in the 1979-1980 study, one by electroshocking in April 1979 at a revetted bank and one in a gill net at Matthews Bend in November 1979. In the pilot study a total of 35 bowfins were collected, with 34 of them coming from lentic areas (6, 10, and 9, respectively, from the abandoned channels of Matthews Bend, Moon Chute, and Carolina Chute, 3 from an oxbow lake, and 6 from a borrow pit). Our data therefore indicate that the bowfin is fairly specific in its habitat choice, preferring a backwater habitat, as indicated by Pflieger (1975) and Buchanan (1976).

Family Anguillidae - American Eel

8. Twenty-three American eels (*Anguilla rostrata*) were collected over 1979-1980, 18 or which were collected with hoop nets and 5 via electroshocking. Eels were collected from the natural banks at Anconia and Island 88, from the revetted bank at Walnut Point, and from both Leota and Lower Cracraft Dike Fields. No eels were collected from the backwaters of Matthews Bend. Similarly, in the pilot study only 1 eel was collected from a backwater habitat. It seems, therefore, that eels prefer the main-stem river to backwater areas.

Family Clupeidae - Herrings

9. The gizzard shad (*Dorosoma cepedianum*) is ubiquitous and abundant in the lower Mississippi River. In Matthews Bend gizzard shad constituted 72 percent of the fish collected using electroshocking during the intensive study, while making up 49 percent of the fish captured with gill nets. Over all sampling dates in 1979 members of this species

made up 88 percent of the fish collected by electroshocking at Lakeport Revetment, 65 percent at Walnut Point Revetment, 72 percent at Anconia Natural Bank, and 79 percent at Island 88 Natural Bank. Similarly, in the dike fields gizzard shad dominated electroshocking and gill net catches. Electroshocking in the dike field areas not only confirmed that gizzard shad were abundant in the pools but also indicated that this species was quite common on the river side of the dike field middle bars.

10. Threadfin shad (*Dorosoma petenense*) showed an interesting distributional pattern. Threadfin shad were found only along the bank habitats (revetted and natural) and in the dike fields in either April and June; i.e. no individuals were collected in the abandoned channel in either of these months. The threadfins collected by electroshocking along the banks in April 1979 (N = 13) had a mean total length of 97 mm and ranged from 86 to 122 mm. By June 1979 mean total length of threadfin shad captured along the banks by electroshocking (N = 19) was 121 mm with total length ranging from 104 to 134 mm. Similarly, threadfins collected by electroshocking from the dike fields in April and June were all of large size (greater than 100 mm).

11. September and November 1979 data show a distribution of threadfins just opposite to that of April and June. In September and November not a single *D. petenense* was found along a natural or revetted bank. Instead, threadfins were present in the abandoned channel at Matthews Bend, a habitat which they did not inhabit in April and June. The individuals collected by electroshocking in Matthews Bend in September and November 1979 were all small individuals [September: $\bar{x}$ = 83 mm, lengths ranged from 75 to 96 mm (N = 16); November: $\bar{x}$ = 82 mm, lengths ranged from 72 to 97 mm (N = 65)]. The threadfins collected in September of 1980 (no threadfins collected in September 1979 dike field electroshocking samples) were all of small size ($\bar{x}$ = 83 mm, all individuals less that 100 mm). Apparently the fairly large individuals inhabit the main-stem of the river in the spring and early summer, spawn, and then die. Younger threadfins inhabit backwater areas (abandoned channels and dike field slack-water pools) in the late summer and autumn.

12. The third clupeid species collected in our lower Mississippi River studies was the skipjack herring (*Alosa chrysochloris*). The skipjack was commonly collected at all the habitats investigated in 1979-1980. Although Buchanan (1976), Pflieger (1975), and Trautman (1981) have characterized the skipjack as being an inhabitant of swift water, this species was also quite common in fish collections made in backwaters such as Matthews Bend and Lake Lee (Tables 11-13).

Family Hiodontidae - Mooneyes

13. Goldeyes (*Hiodon alosoides*) and mooneyes (*Hiodon tergisus*) were collected in both the pilot and the 1979-1980 studies. Goldeyes were more numerous than mooneyes in both investigations (pilot study: goldeye = 26, mooneye = 19; 1979-1980 study: goldeye = 100, mooneye = 12). Goldeyes are more common than mooneyes in both the Arkansas River (Buchanan 1976) and the Ohio River (Trautman 1981). Goldeyes were collected by a wide variety of gear types in both studies, including seining, electroshocking, gill nets, hoop nets, and trammel nets. In the 1979-1980 study a few goldeyes were collected from the backwaters of Matthews Bend, and from the natural and revetted banks. However, the greatest catch of goldeyes per unit effort took place using gill nets, at low flows, in the dike field pools (2.29 goldeyes/net-day in Lower Cracraft Dike Field in September 1980, effort = 17 net-days; 0.83 goldeyes/net-day in Leota Dike Field in September 1980, effort = 12 net-days). The few mooneyes collected in the intensive study were taken only in the dike fields, using seining and electroshocking.

Family Cyprinidae - Minnows

14. Pflieger's (1975) characterization of the river shiner (*Notropis blennius*) as being commonly found in association with the emerald (*N. atherinoides*) and silverband (*N. shumardi*) shiners aptly fits the lower Mississippi River, as we found these three species to be the most abundant minnows in our study area (Table 21). All the minnows

which were abundant in the lower Mississippi River seine hauls have been described as being abundant in large rivers; however, the river and silverband shiners are, for the most part, confined only to large rivers, while the emerald shiner, blacktail shiner (*N. venustus*), speckled chub (*Hybopsis aestivalis*), central silvery minnow (*Hybognathus nuchalis*), and bullhead minnow (*Pimephales vigilax*) are found in a wider range of habitats (Pflieger 1975).

15. The emerald shiner is quite abundant in the lower Mississippi River, and is the most abundant minnow in the Missouri River and the upper and middle Mississippi Rivers (Pflieger 1975). Our data indicate, however, that the river shiner is the most abundant minnow in the lower Mississippi River, with the emerald or silverband shiner the next most common (Table 21).

16. Carp (*Cyprinus carpio*) were fairly common, though not abundant, in the lower Mississippi River study area. In both the pilot study and in the later investigation (1979-1980) carp were collected from all the various habitat types. Because of their large size they were often a dominant fish, by weight, in the various habitats. No goldfish (*Carassius auratus*) were collected in the 1979-1980 study; however, five goldfish were collected in the pilot study.

Family Catostomidae - Suckers

17. River carpsuckers (*Carpiodes carpio*) are abundant in the lower Mississippi River, and are far more numerous than either the quillback (*Carpiodes cyprinus*) or the highfin carpsucker (*Carpiodes velifer*), the two other carpsuckers found in the lower Mississippi River. The ratio of carpsuckers collected in the pilot study was 867 river:19 quillback: 12 highfin; similarly the 1979-1980 study produced a ratio of 384 river: 9 highfin:5 quillback. River carpsuckers are also abundant in the Missouri River (Pflieger 1975) and the Arkansas River (Buchanan 1976) where they exceed both quillbacks and highfins in abundance. Buchanan (1976) characterized the river carpsucker in the Arkansas River as being most numerous in backwaters, but also commonly collected in areas of

various current velocities. Its distribution in the lower Mississippi River study area was similar to that of the Arkansas. The river carpsucker was the most common species collected in the gill nets from Matthews Bend (abandoned channel) at low flows (November 1979), but was also commonly collected from the revetted bank at Walnut Point, the dike fields at all flow stages, and both inside and outside the dike field middle bars at low flow. The river carpsucker was the most common catostomid collected from the lower Mississippi River in both EWQOS investigations.

18. The smallmouth buffalo (*Ictiobus bubalus*) is the most abundant buffalofish in the lower Mississippi River, and is ubiquitous in distribution, being commonly found in backwaters (see Matthews Bend data - November 1979 in Pennington, Baker, and Bond 1983) and in areas of strong current (see Walnut Point-Kentucky Bend Revetment - June 1979 in Pennington, Baker, and Bond 1983). The smallmouth buffalo is also the most abundant buffalofish in other large rivers of east-central North America, including the Arkansas (Buchanan 1976), the Ohio (Trautman 1981), and the middle Mississippi (Pflieger 1975). Bigmouth buffaloes were collected from a number of habitats in the EWQOS studies; however, the largest numbers were collected from backwaters such as abandoned channels or from dike field pools. Only a single black buffalo (*Ictiobus niger*) was collected in the pilot study (and none in the 1979-1980 study) indicating that this fish is uncommon in our study area.

19. The blue sucker (*Cycleptus elongatus*) is very habitat selective, strongly preferring swift current areas of large rivers (Moss, Scanlan, and Anderson 1983; Pflieger 1975; Buchanan 1976). Our intensive study clearly showed this preference for fast water. This species was collected from both natural and revetted banks, with the highest numbers coming along revetted banks (current speeds are generally higher along revetted banks than natural banks in the lower Mississippi). Although blue suckers were fairly commonly collected with hoop nets in the dike field pools at moderate flows (20 and 22 June 1979), this species was virtually absent from collections in the dike field pools at

low flows. No individuals were collected from the backwaters of Matthews Bend throughout the study. Although blue sucker population sizes have markedly declined in the upper and middle Mississippi (Pflieger 1975), our data indicate that fairly sizable numbers exist in the lower Mississippi River.

20. The spotted sucker (*Minytrema melanops*) was occasionally collected in the lower Mississippi EWQOS investigations. Seven individuals were collected in the pilot study; one individual was collected in the 1979-1980 investigation. No redhorses (*Moxostoma*) were captured from our study area in either investigation.

Family Ictaluridae - Catfishes

21. The blue (*Ictalurus furcatus*), channel (*I. punctatus*), and flathead catfish (*Pylodictis olivaris*) are all abundant in the lower Mississippi River. The blue and flathead catfish are more common than the channel catfish in the lower Mississippi: C/f of blue catfish generally exceeds that of channel catfish for hoop net catches (Table 18), gill nets (Table 20), and electroshocking (see electroshocking results in Tables 11, 17, and 19). This is especially significant since the numbers of blue catfish have markedly declined in the upper Mississippi and Ohio Rivers since their impoundment, and the blue catfish is presently less common than the other large catfishes in both systems (Pflieger 1975, Trautman 1981). Although blue catfish commonly occur in lentic areas (see high gill net catches in the dike field pools at low river stage, Table 20), they showed a "preference" for faster water conditions (Figures 30 and 31). Although channel and flathead catfish did not show the clear preference for faster waters shown by *I. furcatus*, all three species were commonly found together in the same habitat (Figures 28 and 29). Flathead catfish were probably underrepresented in catches in lentic areas. While hoop netting seemed to be a good means of collecting flatheads, gill nets and electroshocking were rather poor flathead collectors, i.e., in those situations in which C/f for hoop nets was similar for the three large catfish species, the C/f for gill

nets and electroshocking in the same habitat was much lower for flatheads than for blue or channel catfish.

22. Black (*I. melas*), brown (*I. nebulosus*), and yellow bullheads (*I. natalis*) are fishes of quiet waters, preferring backwaters (Pflieger 1975). Although only small numbers of bullheads were collected during the EWQOS investigations, the individuals that were collected were found only in abandoned channels and oxbow lakes.

Family Cyprinodontidae - Killifishes

23. Two species of topminnows, the blackspotted topminnow (*Fundulus olivaceus*) and the blackstripe topminnow (*F. notatus*), were collected by seining from lower Mississippi River dike fields in the EWQOS investigations. Only small numbers of these fishes were collected; three blackspotted topminnows were collected in the 1979-1980 study while a single individual of *F. notatus* was collected during the pilot study.

Family Poeciliidae - Mosquitofish

24. The mosquitofish (*Gambusia affinis*) was collected by seining from shallow shoreline areas in the lower Mississippi. Middle bars of dike fields and river sandbar islands were found to support mosquitofish populations.

Family Atherinidae - Silversides

25. The silversides family is represented by two species in the lower Mississippi River, the inland silverside (*Menidia beryllina*) and the brook silverside (*Labidesthes sicculus*). The inland silverside, formerly known as the Mississippi silverside, was one of the most common fishes taken in seine hauls, and was almost always more common than the brook silverside. Buchanan (1976) also found the inland silverside to be more common than the brook silverside in the Arkansas River.

Family Percichthyidae - Temperate Basses

26. Two temperate bass species were collected from the lower Mississippi River in both the pilot and the 1979-1980 study: the white bass (*Morone chrysops*) and the striped bass (*M. saxatilis*). Although the yellow bass (*Morone mississippiensis*) is present in the upper Mississippi River (Pflieger 1975) and three yellow bass were reported by NUS Corporation (1974) from the lower Mississippi River in the vicinity of river miles 400-410, no individuals of this species were collected in either of the EWQOS investigations. Pflieger (1975) has described the yellow bass as being more abundant in the Mississippi River above the mouth of the Missouri than below. The yellow bass collected by NUS Corporation (1974) may have had a nearby lake as their source of origin.

27. White bass outnumbered striped bass in both EWQOS investigations. In the pilot study 163 white bass were collected over all habitats, with all gears, while 46 striped bass were captured. In the 1979-1980 study 181 white bass were collected, along with 12 striped bass. Seining in Cracraft and Leota Dike Fields in June 1979 showed fairly large numbers of young-of-the-year white bass concentrated along the river side of the middle bar.

Family Centrarchidae - Sunfishes

28. The centrarchid species collected in the 1979-1980 study included the warmouth (*Lepomis gulosus*), orangespotted sunfish (*L. humilis*), bluegill (*L. macrochirus*), longear sunfish (*L. megalotis*), redear sunfish (*L. microlophus*), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), and black crappie (*P. nigromaculatus*). An identical centrarchid list was engendered from the 1978 pilot study with the exception of a single spotted bass (*Micropterus punctulatus*) which was collected in that study. Table 15 shows that the bluegill was the most widely distributed centrarchid in the study area. Buchanan (1976) has described the bluegill as being the most widely distributed sunfish in the Arkansas River system. White

crappie, black crappie, and largemouth bass are also fairly common in the lower Mississippi River, while warmouth, orangespotted, longear, and redear sunfish are relatively uncommon (Tables 15 and 16). Few centrarchids were collected along the bank habitats (Table 15), and the greatest diversity and abundance of centrarchids was in the backwaters of Matthews Bend (Tables 11, 15, and 16). Within the backwater, bluegills, crappies (black and white), and largemouth bass were the most abundant centrarchids (Tables 11 and 16). Hoop net data collected in November 1979 indicate that the dike field pools also supported centrarchid populations at low flows (Pennington, Baker, and Bond 1983), with bluegills most common, followed by white crappie, and then black crappie.

Family Percidae - Perches

29. Saugers (*Stizostedion canadense*) seem to be much more common than walleyes (*Stizostedion vitreum*) in the large rivers of east-central North America. In the Arkansas River the sauger is "widely distributed" and is "not uncommon" (Buchanan 1976) while no valid records of the walleye occur. The sauger is presently much more common than the walleye in the Ohio River (Trautman 1981), and sauger outnumber walleye by an approximate 9:1 ratio in the upper Mississippi River (Pflieger 1975). While saugers were fairly commonly collected in the lower Mississippi River EWQOS studies, no walleyes were collected, indicating that *S. vitreum* is either rare or absent from the lower Mississippi. Although saugers have been characterized as preferring a strong current (Pflieger 1975, Buchanan 1976), we collected saugers in appreciable numbers from the dike field pools at low flow (Table 20) as well as from areas of swifter current such as revetted banks. Young-of-the-year sauger were fairly common in seine hauls along the dike field middle bars in June.

30. Two individuals of the bluntnose darter (*Etheostoma chlorosomum*) were collected in the pilot study. Both individuals were collected by seining along a river sandbar.

Family Sciaenidae - Drum

31. The freshwater drum (*Aplodinotus grunniens*) is abundant in the lower Mississippi River. It is a very common fish in other large rivers, including the Arkansas (Buchanan 1976), the Missouri and upper and middle Mississippi (Pflieger 1975), and the Ohio (Trautman 1981). In addition to being abundant, this species is ubiquitous in the lower Mississippi having been commonly collected from all the habitats investigated in the 1979-1980 study. Drum was one of the dominant fishes (along with the three large catfishes and river carpsucker) captured in the hoop nets placed in the strong currents which existed in the dike fields in June 1979. Yet drum were also caught in large numbers in the gill nets set in the quiescent dike field pools at low flows (Table 20) and in the abandoned channel (Matthews Bend) (C/f = 7.83 drum/net-day in June 1979 and 6.17 drum/net-day in September 1979).

Family Mugilidae - Mullets

32. The striped mullet (*Mugil cephalus*) is a marine species that occasionally ascends large rivers. A total of 14 individuals were collected over the 1979-1980 study, 13 by electroshocking and 1 in a gill net. All the striped mullet were collected from the main-stem habitats (natural and revetted banks and dike fields); i.e. none were collected from Matthews Bend. Sampling by the Federal Water Pollution Control Administration in 1966-1968 (NUS Corporation 1974) showed that the striped mullet was abundant at Luling, La. (river miles 117-125), fairly common at Talbert Landing, La. (river miles 300-310), and occasionally collected at Vicksburg, Miss. (river miles 432-452). The EWQOS study area is therefore near the northern end of the striped mullet's range in the lower Mississippi River. This species has also been reported from the Arkansas River (Buchanan 1976) and a number of coastal rivers (Hoese and Moore 1977, Lee et al. 1980).

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